ESSAYS ON HEALTH, INEQUALITY AND FAIRNESS

ON THE MEASUREMENT AND INTERPRETATION OF HEALTH INEQUALITY, INCOME INEQUALITY, AND INCOME-RELATED HEALTH INEQUALITY

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Lay Abstract

This thesis concerns itself with different aspects of inequality related to health and income, though the focus differs across chapters. The second and third chapters of this thesis contribute to a greater understanding of the measurement and interpretation of inequalities. Whereas the fourth chapter provides empirical evidence on how country-specific policies can counteract or exacerbate health differences. Chapter 2 comprehensively reviews and critically assesses the literature on the technical and normative properties of indices commonly used for measuring income-related health inequality thereby addressing the gap between the requirements of these indices and current research practice. Chapter 3 investigates public attitudes toward inequalities in income, health, and income-related health inequality to determine preferences and where attitudes toward these inequalities differ. Chapter 4 examines global health inequalities that result from medical care use using the example of long-standing drug technologies for treating hypertension and links availability and affordability of medicines with individual use and health outcomes.

Abstract

Governments, international agencies, and researchers routinely assess health and income inequalities and inequities so as to better communicate the evidence of their levels and trends to both policy-makers and the general public. Measuring the extent to which differences in health or income are unequal or unfair is, however, complex. This thesis contains three chapters centrally concerned with inequalities, though the focus differs across chapters. Chapter 2 helps address the gap between the requirements of indices often used for measuring income-related health inequality and current research practice by providing a non-technical review and critical assessment of the recent literature. This chapter should function as a guide for policy researchers and analysts to help them be more critical consumers of studies that use these indices while also helping applied researchers in choosing inequality measures that have the normative properties they seek. Most measures of inequality make assumptions about the extent to which society is averse to inequality. Moreover, analysts often assume that attitudes toward inequalities in health or income are the same. Chapter 3 is the first study using a mixed-methods approach to assess public attitudes toward inequalities in income, health, and income-related health inequality to determine preferences and how attitudes toward inequalities in these domains differ. Chapter 2 and 3 contribute to a greater understanding of the measurement and interpretation of inequalities.

While chapters 2 and 3 focus on inequalities among individuals within a society, chapter 4 focuses on inequalities globally among societies. Chapter 4 examines global health

inequalities that result from medical care use using the example of long-standing drug technologies for treating hypertension. The study links availability and affordability of blood-pressure-lowering medicines with individual use and health outcomes. Chapter 4, therefore, provides an empirical illustration on how country-specific policies can play an important role in either countering or exacerbating health differences.

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This thesis is dedicated to my grandmothers. I was able to choose a path of further education. While you shared an appreciation of education this path was unavailable to you simply because of circumstances beyond your control. These chapters are written in loving memory of my grandfathers. One a firm advocate of social justice and fairness, a philosophy he maintained in all his interactions, personal and professional. The other a victim of social injustice.

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Chapter 3 Attitudes toward inequalities in income and health

List of abbreviations

ACE	Angiotensin-Converting Enzyme
AR	All-response
ARBs	Angiotensin II Receptor Blockers
BP	Blood pressure
CCHS	Canadian Community Health Survey
CI	Concentration Index
CPI	Consumer Price Index
CRRA	Constant Relative Risk Aversion
CTP	Capacity-to-pay
CVD	Cardiovascular diseases
ECI	Extended Concentration Index
EDE	Equally Distributed Equivalent
EM	Expectation minimization
EPOCH	Environmental Profile of a Community's health
fMRI	functional Magnetic Resonance Imaging
FR	First-response
FT	Full-time employment
GCI	Generalized Concentration Index
GDP	Gross Domestic Product
GNI	Gross National Income
HALE	Health adjusted life expectancy
HIC	High-income countries
HUI	Health Utilities Index
IA	Inequality aversion
IIA	Independence of Irrelevant Alternatives
IQR	Inter-quartile range
LC	Latent class
LIC	Low-income countries
LMIC	Low-middle-income countries
ML	Maximum likelihood
OECD	Organisation for Economic Co-operation and Development
OR	Odds ratio
PPP	Purchasing power parity
PURE	Prospective Urban Rural Epidemiological
RIF	Re-centered influence function

RUM	Random Utility Model
SES	Socio-economic-related
SVO	Social values orientation
SWF	Social welfare function
UMIC	Upper-middle income countries
WHO	World Health Organisation
WHS	World Health Survey

Declaration of Academic Achievement

This dissertation contains three original research studies (chapters 2, 3, and 4), an introduction (chapter 1) and conclusion (chapter 5). I, Marjan Walli-Attaei, am the lead author of these chapters. In collaboration with my supervisor, Dr. Jeremiah Hurley, I conceived the research questions, conducted the data collection, analyses, and preparation of chapters 2 and 3. Dr. Jeremiah Hurley provided substantive comments on all the drafts of this dissertation. Members of my supervisory committee, Dr. Michel Grignon and Dr. Emmanouil Mentzakis, provided feedback on earlier drafts which informed the final version of the dissertation. Dr. Emmanouil Mentzakis recommended the structural model extensions and oversaw the programming and estimation of these models for the analyses presented in chapter 3.

Chapter 4 is a co-authored publication in which I had the primary responsibility for the design and execution of the statistical analyses and writing of the manuscript. Dr. Salim Yusuf conceived and initiated the PURE study, supervised its conduct and data collection; he reviewed and revised all drafts of this manuscript, and oversaw my work. Other co-authors commented on earlier drafts.

Chapter 1 Introduction

Background:

Monitoring inequalities in health and income matter a great deal to international financial institutions such as the International Monetary Fund and the World Bank and to the international political and social institutions such as the United Nations where reducing inequality is one of the 17 Sustainable Development Goals. Health and income inequalities have also garnered much public attention (Pew Research Center, 2014). As a result, governments, international agencies, and researchers routinely assess measures of health and income inequalities so as to better communicate the evidence of their levels and trends to both policy-makers and the general public. However, disagreements on both the extent and importance of health and income inequality remain; thereby, leading to the following questions. Are these disagreements partially due to the different normative assumptions about how to measure inequality? Do people view inequalities in health and income equivalently? Under what conditions are the inequalities that result from differences in access to medical care unfair?

To address these questions, this thesis concerns itself with different aspects of inequality related to health and income which, it is argued, are closely intertwined and are important constituents of wellbeing. As Aristotle argued in *Ethics*, health and income are also crucial to "the good life and the good of society" (Adler, 1952). The primary focus of the chapters, however, are inequalities in health.

Health differences across people or groups of people are not always *prima facie* unjust. We observe differences in health for a variety of reasons. Some of these are deemed objectionable (e.g., systematic differences in premature child mortality determined by the parents' socioeconomic status), whereas others are deemed legitimate (e.g., health differences by age). While some differences evoke strong ethical responses among most people, there is substantial heterogeneity in attitudes toward inequalities. These differences may partially explain why there are contentious discussions, within policy circles and among researchers, on the topic of health and income inequality, on their causes and consequences, and the possible solutions for addressing them.

Health differences also arise from innovations, such as advancements in health care, and through the international trade (or lack thereof) of health-related goods and services, such as medicines. More-educated people tend to take earlier advantage of new health technologies than less-educated people (Glied & Lleras-Muney, 2008). People in wealthier countries tend to gain access to new technologies and health-related information more quickly than people in poorer countries (Banerjee & Duflo, 2011). In turn, these differences in access to information and to innovations reinforce existing health inequalities or create inequalities where none previously existed. For example, in response to the U.S. Surgeon General's famous 1964 report on the harmful effects of smoking, more-educated people readily changed their behaviour, thereby generating the social gradient in lung cancer that persists today (Deaton, 2013). Deaton (2013) eloquently captures this phenomenon in his description of inequality "as the handmaiden of progress" (page 6). Inequality, however, is not the same as unfairness: inequalities are differences, *inequities* are unfair differences (Hurley, 2010). Discussions about inequality are often discussions about unfair inequalities (Starmans, Sheskin, & Bloom, 2017).

Measuring the extent to which differences in health are unequal and unfair is complex. Such assessments require considering how to measure these differences, for example, through obtaining valid measures of health; understanding the causal relationships, such as the determinants of health; and recognizing the statistical limitations encountered when estimating the relationship between health and its determinants. Such assessments also require making a series of value-laden choices during the measurement process regarding, for instance, the chosen health variable, the chosen comparison groups (unequal in comparison to whom), and the units of analysis. Importantly, such assessments often involve several *implicit* normative judgements on fairness. These implicit normative judgements tend to reside within measurement tools, often under the guise of technical properties, and they include assumptions regarding who matters, by how much, and relative to whom. Even the definition of the most unequal society, (i.e., the distribution of health or income that generates the most inequality), is an implicit normative judgement. While analysts continue to debate the merits of alternative conceptions of fairness, it remains unclear whether public attitudes toward inequality align with the assumptions of fairness that are implied in commonly used measurement tools. It is arguable that, in democratic societies, the normative assumptions on the extent to which inequalities in health and income matter should accord with the values held by members of these societies. Further, *assumptions* on the notions of fairness play an important role in determining the measurement of inequality and its extent.

Although more attention is being focused on these implicit normative judgments, discussions on these judgements are often highly technical and are communicated in disparate disciplinary journals, thereby making them inaccessible to key audiences. In many cases, more empirical research is needed to better inform decisions about the assumptions made when measuring inequality. It is also important to better understand how to interpret estimates of inequality before devising policies to address them.

The second and third chapters of this thesis focus on the implicit normative judgments that are part of the assessment of inequality and aim to inform ways in which assessments of inequality can be improved. The fourth chapter examines global health inequalities that result from medical care use using the example of long-standing drug technologies for treating hypertension. While chapters 2 and 3 focus on inequalities among individuals within a society, chapter 4 focuses on inequalities globally among societies.

Knowledge gaps and objectives:

The specific gaps in the literature that motivate each of the three chapters are described below along with a description of each chapter's objectives:

I) The literature on health inequalities tends to focus on the socioeconomic dimension of health inequalities. The most common tool for measuring socioeconomic-related health inequalities is the concentration index. However, several variants of the concentration index have been proposed and these indices have important technical and normative differences. It is becoming increasingly difficult to keep track of these indices because the literature can be highly technical and the discussions are spread among disparate disciplinary journals. Hence, chapter 2 seeks to comprehensively review and critically examine the literature on the technical and normative properties of the concentration index based indices in order to a) help applied researchers choose inequality measures that have the normative properties they seek, and b) provide a guide for policy researchers and analysts to help them be more critical consumers of studies that use the concentration index based indices.

II) Most measures of inequality make assumptions about the extent to which society is averse to inequality, and analysts often assume that attitudes toward inequalities in health or income are the same. It remains unknown whether preferences toward inequalities in health and income differ. Chapter 3 therefore addresses public attitudes toward inequalities in income, health, and income-related health inequality to determine preferences and where attitudes toward these inequalities differ.

III) Information on the access to essential medicines is unreliable or simply unknown in some regions of the world, such as in low- and middle-income countries. Moreover, the extent of differential access to essential medicines across countries with varying levels of economic development and its health consequences has not been established. Chapter 4 provides an empirical illustration of inequalities that result from differential access to long-standing drug technologies for treating hypertension.

Below, I briefly describe how each of the objectives is achieved.

Chapter 2 provides a non-technical review and critical assessment of the literature describing the interrelationship between the technical and normative properties of concentration index based (CI-based) indices. In doing so, this conceptual chapter should function as a guide for policy researchers and analysts to help them be more critical toward studies that use the CI-based indices. This chapter also aids applied researchers in choosing inequality measures that have the normative properties they seek. The overarching research question addressed in chapter 2 is: what are the consequences of the normative assumptions embedded within the CI-based indices for estimates of socio-economic-related health inequality? This conceptual study goes beyond providing a straightforward review, commentary, and critique of the CI-based indices. This chapter links concepts, at times from across disciplines, and integrates parts of the current literature, using empirical examples and figures. Chapter 2 also provides a review of current research practices and describes how these align with properties of the indices. By describing the implications of current research practices, this chapter offers insights for future researchers wanting to assess socio-economic-related health inequalities.

Chapter 3 investigates public attitudes toward inequalities in health and income by quantifying inequality aversion (IA). The overarching research question is: are the publics' attitudes toward inequality in health and income different? Using a sample of the general public in Ontario, Canada, chapter 3 involved designing and implementing a stated-preference experiment to empirically estimate inequality aversion over univariate distributions of each of health and income, and a bi-variate distribution of income-related health inequality. Descriptive qualitative methods were used to investigate the underlying arguments and justifications participants provided for their inequality judgements. This chapter builds on chapter 2 by empirically estimating the degree of inequality aversion in a society, a parameter for which an assumed value is embedded in most inequality measurement tools.

Chapter 3 is the first study to empirically assess inequality aversion preferences in both univariate distributions of health and income and a bivariate distribution of income-related health inequality using a mixed-methods approach. In understanding public attitudes toward inequality, we can better understand the extent to which a current income or health distribution falls short of what is considered ideal. Moreover, there is increased interest in explicitly incorporating inequality aversion preferences into economic evaluations, such as in cost-effectiveness analyses (Asaria, Griffin, & Cookson, 2016; Cookson, Drummond, & Weatherly, 2009). The empirically derived estimates of inequality aversion can inform these other applications.

Chapter 4 provides an empirical illustration of how differential access to medical treatment can create global health inequalities. The example of access to hypertension medicines was used because hypertension is considered the most important modifiable risk factor for cardiovascular diseases. The hypertension medicines included as part of the analyses have been shown to be safe, effective, are all off-patent, and all are listed on the World Health Organization's model list of Essential Medicines. The overarching research questions here are: i) to what extent are hypertension medicines available and affordable in countries with varying degrees of economic development, and ii) what is the association between availability, affordability and use of hypertension medications and hypertension control? This chapter used data from 20 countries participating in the Prospective Urban Rural Epidemiological (PURE) study. Availability of medicines was measured by whether the medicines were physically present in the local pharmacy. Affordability was estimated using the concept of household capacity-to-pay. Availability and affordability were then related to the use of the hypertension medicines and to blood pressure control. The results were compared for high-income, upper-middle-income, lower-middle-income, and low-income countries.

This published study is the first to link availability and affordability of blood-pressure-lowering medicines with individual use of these medicines and health outcomes (lack of blood pressure control) in high-, middle-, and low-income countries. Chapter 4 demonstrates that, while health inequalities can and do result from well-intentioned medical innovations, country-specific policies can play an important role in either countering or exacerbating some of these health differences. In the case of hypertension medicines, policies related to the procurement of essential medicines as well affordability, appear to affect use of blood-pressure-lowering medicines.

Taken together, chapters 2 to 4 provide insights that can inform assessments of health and income inequalities (chapters 2 and 3), or the types of policies that may reduce global health inequalities (chapter 4). Finally, chapter 5 summarizes the key findings from chapters 2 to 4, highlights their contributions to the literature, and concludes with some policy implications.

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Chapter 2 On the interpretation of concentration based indices for measuring socio-economic-related health inequality: a review of current research practice

Preface:

This chapter has been submitted to a journal for publication. I conceived the research question and had the primary responsibility of writing this chapter. Jeremiah Hurley and Paul Contoyannis reviewed and revised all drafts of this manuscript, oversaw my work, and provided substantive feedback which informs the final manuscript.

Abstract

Concentration index based measures are the most popular tools for estimating socio-economic-status (SES) related health inequalities. In this study we provide a non-technical review and critical assessment of these indices. We discuss the difficulties that arise when measurement tools intended for income are used in the health context and describe and illustrate the interrelationship between the technical and normative properties of these indices. A focal point of our review is the alignment of current research practice with the properties of the indices used. We reviewed 44 empirical studies published between 2015 and 2017 and find that researchers often fail to provide meaningful interpretations of the index estimates. For example, our review of empirical studies revealed that 95% used bounded health measures, but only half acknowledged that the range of the index varies when the outcome is bounded. Only 5% of studies explicitly presented the estimates in relation to their minimum and maximum. Moreover, several studies made comparisons of SES-related health inequality across indices. These comparisons are confusing since changes or differences in estimates across indices are rarely equivalent. To address these shortcomings, we propose a series of questions to facilitate further sensitivity analyses and provide a better understanding of the index estimates. In doing so, we also provide a guide for researchers and policy analysts to help them be more critical consumers of studies that use these indices, while also helping applied researchers to choose inequality measures that have the normative properties they seek.

1.0 Introduction

The Concentration Index (CI) is an increasingly popular measure of socio-economic-related (SES) health inequalities. The CI's popularity is partly attributable to its many desirable properties, such as its decomposability into factors contributing to observed inequality, its use of information from the full distributions of health and income, and its amenability for statistical inference (see, e.g., O'Donnell et al., 2008). But the CI is not without controversy. Originally developed in the context of measuring *income* inequality (Kakwani, 1980), some argue that the CI has problematic properties as a measure of SES-related *health* inequality. The CI, for example, assumes that health is measured on an unbounded, ratio scale and that health can be transferred among members of society. Controversy regarding properties of the CI has spawned the development of several closely-related alternatives to the CI that address its perceived shortcomings, these include the Extended Concentration Index (Wagstaff, 2002), Generalized Concentration Index (Clarke et al., 2002), Generalized Extended Concentration Index (Erreygers et al., 2012), Symmetric Index (Erreygers et al., 2012), Erreygers Index (Erreygers, 2009) and Wagstaff Index (Wagstaff, 2005). We will call these the CI-based indices.

This controversy and the associated proliferation of the CI-based indices are rooted in the intertwining of technical properties and normative assumptions in inequality measurement such that, what may appear to be purely technical matters have (often) underappreciated normative implications. These normative implications pertain, for instance, to what constitutes inequality or how much one cares about health inequality at different parts of the income distribution. For non-specialists who simply seek to apply a suitable measure of inequality or to interpret the current evidence on the nature and extent of socio-economic-related health inequalities, these debates can be arcane, confusing, and inaccessible both technically and because they are spread among disparate journals. Understanding the issues and options for measuring inequality is important: different CI-based indices can lead to different empirical conclusions regarding the extent of inequality, whether inequalities differ across jurisdictions, and whether inequalities have increased or decreased over time within a jurisdiction. Further, such understanding can help practitioners choose inequality measures more consistent with the underlying values of the setting in which inequality is being measured.

This paper examines in a non-technical way many of the core issues in the debate about alternative CI-based measures of socio-economic-related health inequality, with the goal of helping policy researchers and policy-analysts be more critical consumers of this literature and helping applied inequality researchers choose inequality measures that embody the normative properties they seek. We examine ways in which health differs from income that matter for the measurement of SES-related health inequality, and highlight how describing, estimating and evaluating health inequalities are intrinsically technical and value-laden exercises. Throughout the paper, we contextualize our arguments using the results from a comprehensive review of recently published empirical studies (between 2015 and 2017) that apply the CI-based indices to obtain estimates of

SES-related health inequality. (See Appendix 2.1). This review of current research practice serves to empirically illustrate how well current research practice aligns with the properties of the indices used. By making the linkages between normative judgments on fairness and their manifestation in the technical measurement *process* explicit, we clarify the type of information the CI-based indices provide, when they are appropriate, and their limitations.

2.0 The Concentration index based indices

The CI is a bivariate inequality index: it measures how inequality in one variable (e.g., health) relates to variation in a second variable (e.g., socio-economic status). The CI derives from the concentration curve. A *concentration curve* plots the cumulative shares of a health variable (vertical axis) against cumulative shares of the population, ranked by an indicator of socioeconomic status[1] (horizontal axis) (O'Donnell et al., 2008). Figure 2.1 displays concentration curves for the populations of three hypothetical countries, A, B, and C. If everyone in a population has the same value of health, so that health is distributed perfectly equally, the concentration curve will be a 45^0 line—the line of equality. Any deviation from the 45^0 line indicates SES-related inequality, and the amount of inequality can be measured as a function of the deviation between the line of equality and the observed concentration curve across the income distribution. In

[1] Most analyses use income as the measure of socioeconomic status, but other measures can be used such as social class, educational attainment, and consumption. Debate about how best to measure socioeconomic status is beyond the focus of this paper; we assume one has a valid measure of socioeconomic status.

particular, the CI, hereafter referred to as the standard CI, is equal to twice the area between a concentration curve and the line of equality, and, under conditions we discuss below, it takes on values from -1 to +1. By convention, the standard CI and the CI-based indices more generally, are positive when a concentration curve lies below the line of equality, such as countries A and B in Figure 2.1, implying that higher socioeconomic groups have better health (often referred to as a “pro-rich” distribution), and are negative when it lies above the line of equality, such as country C, implying that lower socioeconomic groups have better health (often referred to as a “pro-poor” distribution). The standard CI can equal zero in two situations: when there is no socioeconomic-related health inequality, so the standard CI coincides with the line of equality; and when the concentration curve crosses the line of equality and the areas above and below cancel each other out (O’Donnell et al., 2008). If one concentration curve (e.g., for country A) lies everywhere closer to the line of equality than another (e.g. country B), all CI-based indices would indicate less SES-related inequality in A than Country B. But if concentration curves cross, different CI-based indices can rank the countries differently with respect to the amount of socio-economic-related health inequality. Such differences arise because when concentration curves cross, ranking distributions by the degree of inequality depends on the weights given to different parts of the SES distribution. Different weighting functions can lead to different rankings of inequality even when based on the same concentration curves. Importantly, different weighting functions embody different normative judgments, a point we discuss in greater depth below.

All CI-based indices are rank-dependent measures of inequality. The defining characteristic of a rank-dependent index is that calculation of the index value requires ranking the population from lowest to highest with respect to a characteristic of interest—recall that the population in Figure 2.1 is ranked from lowest to highest socio-economic status. All rank-dependent measures of inequality take the following generic form (Kjellsson and Gerdtham, 2013):

$$I(h) = f(\mu_h, n) \sum_{i=1}^{n} z_i h_i \qquad (1)$$

where n represents the population size, *i* represents a single individual in the population, μ_h represents average health in the population, $f(\mu_h, n)$ is a re-scaling or normalization function, and $\sum_{i=1}^{n} z_i h_i$ is a weighted sum of the health measure h_i with weight z_i for individual *i*. Hence, *all* rank-dependent indices are weighted averages of the outcome variable of interest: different indices simply specify different weights (z_i) and/or normalization functions (f(.)). These different weighting and normalization functions embed normative assumptions that generate controversy.[2] The standard CI, for example, takes the following form:

$$C(h) = \frac{2}{n^2 \mu_h} \sum_{i=1}^{n} z_i h_i \qquad (2)$$

[2] Differences in the weights (*z*) affect the relative contribution of each observation to the index, while differences in normalization factor (f(.) affect the absolute contributions of the observations to the index, depending on the mean level of health and the size of the population.

while the Erreygers Index is specified as:

$$E(h) = \frac{8}{n^2(b_h\text{-}a_h)} \sum_{i=1}^{n} z_i h_i \tag{3}$$

where b_h represents the upper bound of the health variable and a_h represents the lower bound of the health variable.

The only difference between (2) and (3) is the normalization function, though even small differences in the normalization function can have important implications for inequality measurement, such as which distribution of the outcome constitutes the maximum amount of SES-related health inequality in society (i.e., the most unequal society). For the standard CI, the extended CI and the generalized CI, for example, maximum SES-related inequality occurs when either the richest *person* has positive health and all others have 'zero' health or the poorest person has positive health and all others have 'zero' health. For the Erreygers index the maximum SES-related inequality arises when the richest 50% have *all* the health; for the Wagstaff index, the maximum SES-related inequality arises when a given richest *proportion* of the population has full health, where this proportion depends on mean health in the population (Kjellsson and Gerdtham, 2013). Hence, the variants of the standard CI can represent different conceptions of the very nature of inequality in a population.

Before exploring links between technical and normative properties of the standard CI and the CI-based indices in more detail below, we first consider some implications when *health* rather than income is the outcome of interest.

3.0 Health measures and the CI-based indices

Every inequality index assumes that the outcome measure (e.g., life years gained, number of physician visits, presence or absence of disease) satisfies certain measurement properties such as the range and the measurement scale, viz., nominal, ordinal, interval, and ratio. An estimate of inequality is valid only to the extent that measurement properties assumed by the chosen index match those of the outcome measure. Although the standard CI is widely used in health inequality measurement, it was developed to measure aspects of income inequality, and health measures often have properties quite distinct from those of income and other monetary measures. We focus on two measurement properties: the *range* and the *measurement scale* of the outcome measure.

Income has an unbounded, positive range; in principle, it can take on infinitely large positive values. Unlike income, the range of a health measure is often strictly bounded; indeed, health measures are often doubly bounded, with finite, fixed lower and upper values. Dichotomous measures indicating the presence or absence of a condition (low birth-weight, diabetes, death, etc.), for example, can take on one of only two values; measures of health-related quality of life often have a defined range (e.g., 0-1). Even measures such as life-expectancy are, many argue, double bounded by 0 (birth) and a biological maximum length of life (e.g., Dong et al., 2016). For a doubly bounded health measure, health can be measured either by health attainment (e.g., health-related quality of life; life-expectancy) or by health shortfall (e.g., deviation from full health, life-years lost;), and we observe both in the literature. As we will see below, many CI-based inequality indices assume an unbounded range, so the bounded ranges of many health measures will have important implications for the choice of inequality index.

The measurement scale of an outcome reflects the quantitative information embedded in the measure and determines the mathematical manipulations that can *legitimately* be applied to it. Health is generally measured on ordinal, interval, or ratio scales. Health measured on an ordinal scale, such as self-assessed health, indicates only whether health is greater or less than some reference point, but does not provide any quantitative information about how much greater or less. That is, we know that someone who reports that they are now in excellent health rates their health as better than previously when they said they were in poor health, but we don't know how much better. Given this limited quantitative information, strictly speaking, it is not valid to calculate averages or differences for health variables measured on an ordinal scale. For health measured on an interval scale, such as the Health Utilities Index (Horsman et al., 2003), which fix the zero point by convention (0 = dead), differences have quantitative meaning, so addition and subtraction are valid but multiplication and division are not. Finally, for health measured on a ratio scale for which there is a naturally defined zero point, such as weight or life-expectancy, all arithmetic operations are valid. As with the range, the measurement scale is important because different inequality indices make differing assumptions about the measurement scale for the outcome of interest. The standard CI, for instance, assumes that the outcome is measured on an unbounded, ratio-scale.

Because the measurement scales of typical income measures are the same—unbounded and ratio scale—discussion of these issues have not figured prominently in the literature on income inequality, and little thought was given to them when the standard CI was first used in the field of health inequality measurement. But as applications of the standard CI to health inequality measurement grew, often applied to varied health measures with different measurement scales, analysts recognized the incompatibility between the properties of some measures and the requirements of the standard CI (Erreygers, 2009; Erreygers and Van Ourti, 2011; Wagstaff, 2005). In our review of empirical studies using the CI-based indices, for example, only 9 of 44 studies reviewed used a ratio-scaled health measure. For most of the studies, the health measure was dichotomous: 40 out of 44 studies (some studies had more than one health measure)[3]. The measurement scale was unclear in 2 of the 44 studies. Many of the newly developed variants of the standard CI, such as the modified CI, the Generalized CI, the Wagstaff index, and the Erreygers index

[3] Earlier studies have used self-assessed health, an ordinal variable, by mapping a cardinal scale on the categories, see Fleurbaey and Schokkaert (2011) for a discussion. As discussed by Fleurbaey and Schokkaert (2011) and Erreygers and Van Ourti (2010) and shown empirically in a meta-regression by Costa-Font and Hernandez-Quevedo(2015), the chosen zero point of this rescaling procedure independently affects estimates of SES-related health inequality.

attempt to relax these assumptions about the measurement properties of outcome variables, making them better-suited for health inequality measurement.

The boundedness of health variables raises an additional issue: when the outcome measure is bounded, the range of possible values for some CI-based indices, such as the standard CI, depends on the mean of the health variable in the population (Erreygers, 2009; Erreygers and Van Ourti, 2011; Wagstaff, 2005). In such cases, as average health in a population increases the range of possible values for the standard CI narrows (see Figure 2.2) (Wagstaff, 2005). Since the underlying scale of the same index can differ for populations with different means, values of the index are not directly comparable. In these situations, the analyst can use an index that has a fixed range, such as the Wagstaff index, or some suggest calculating the minimum and maximum range of the index and expressing the point estimates as a fraction of the bounds (Wagstaff 2005). Our review of empirical studies revealed that the vast majority of the studies (40 out of 42[4]) used bounded health measures. Despite this, only 20 of the 40 studies acknowledged that the range of the index may vary when the outcome is bounded. Even fewer—only 2 of 40—explicitly present the estimates in relation to the minimum and maximum range of the index. As noted, this matters for the interpretation of index estimates: if the distribution means differ notably, comparing inequality estimates can be misleading even when they are calculated using the same index.

4 The measurement scale and range was unclear in 2 of 44 studies.

4.0 CI-based Inequality indices and implicit definitions of inequality

Everyone can agree on the presence or absence of inequality: inequality is present when the observations are not all equal. But quantifying *the degree* of inequality among differing unequal distributions is both challenging and subject to considerable disagreement about the differences in distributions that constitute greater or lesser inequality. Unavoidably, every inequality index embeds specific, often implicit, assumptions about the aspects of a distribution which affect the measured degree of inequality. We consider three assumptions embedded in every index: a) the types of changes to an *entire* distribution which leave inequality unchanged; b) types of changes to *parts* of a distribution which leave inequality unchanged, c) the characterization of the most unequal distribution of health in a society. To further elucidate these concepts, Table 2.1 illustrates how the different indices respond to these types of changes using a hypothetical example with a population of five people. The population is ranked from lowest to highest income, and life-expectancy is used as the measure of health. Income-related health inequality is calculated using six indices: the standard CI, the extended CI, the generalized CI, the symmetric index, the Wagstaff index, and the Erreygers index. The minimum and maximum range of the indices are presented in brackets.

4.1 Uniform changes to the entire distribution of health: relative versus absolute indices

Let I(h) represent an index of inequality, where h refers to the full distribution of health in a population and h_i to the health of individual i. Suppose everyone's health increases proportionately by 5 percent, so that h_i(after) = 1.05*h_i(before) for everyone (i.e., all i). Has inequality changed? A *scale invariant* index, such as the standard CI, says no, inequality has not changed, so I(h_after) =I(h_before). In Table 2.1 for example, note that the standard CI for distributions 1 and 2 are the same (0.095). Scale invariance means that uniform, equiproportionate changes to an entire distribution leaves measured inequality unchanged. Scale invariance is valuable in some contexts. For multi-country comparisons of an outcome measured in monetary units, such as health expenditures, scale invariance means that the estimated amount of inequality is the same regardless of which jurisdiction's currency is chosen as the common currency.

A second type of uniform change to a distribution arises when everyone's health changes by the same absolute amount: h_i(after) = h_i(before) + h_bar for everyone. Again, we can ask, has inequality changed? A *translation invariant* index, such as the generalized CI, says no (the value equals 7.04 for both distributions 1 and 3 after a 5-year increase in life expectancy for everyone). Translation invariance means that uniform, absolute changes to an entire distribution leaves measured inequality unchanged. Note, however, that the value of the standard CI, which is a scale invariant index, differs for distributions 1 and 3 (0.095 and 0.089). This is because scale invariance focuses on ratios while translation invariance focuses on differences.

While scale and translation invariance are commonly presented as technical properties, whether uniform relative or absolute changes to a distribution leave inequality unchanged is a normative matter. The normative implications of scale-invariance and translation-invariance have been discussed both in the health inequality literature (see for example, Asada, 2010; Harper et al., 2010; Kjellsson et al., 2015; Wagstaff, 2015) and the income inequality literature (see for example, Kolm, 1976; Subramanian, 2014). The income inequality literature generally favors relative measures of inequality, and in fact, absolute measures of income inequality are seldom used (Atkinson and Brandolini, 2004). This is partly because scale invariance allows for real (rather than nominal) comparisons across space and time (Atkinson and Brandolini, 2004; Subramanian, 2014). Absolute measures of income inequality create complications arising from the conversion from monetary to real quantities. Within the health inequality literature, some (e.g., Fleurbaey and Schokkaert, 2009; Mackenbach, 2015) have favoured absolute measures of inequality. Fleubaey and Schokkaert, for example, argue that the absolute measurement approach aligns with their preferred equity framework derived from the literature on responsibility and compensation (Fleurbaey and Schokkaert, 2009, page 75). Others, such as Wagstaff (2015), have argued that reductions in absolute inequality are less common in practice and more difficult to achieve compared to reductions in relative inequalities. This difficulty in reducing absolute inequalities arises because a much larger percentage change is required for those with initial lower levels of health than for those with initial higher levels of health. In Table 2.1, an increment of 5 years for everyone (distribution 3) is equivalent to an 8% increase in life expectancy for quintiles 1 and 2 but only a 5% increase for quintile 5.

We have limited evidence regarding how people judge the impact of absolute versus relative changes on inequality. In the context of income inequality, the limited empirical evidence indicates that people differ in their views on inequality. In one study, a third of respondents made choices consistent with scale-invariance, and a sixth of the respondents made choices consistent with translation-invariance (Amiel and Cowell, 1999).[5] A separate study also found that a third of the respondents made choices consistent with scale-invariance and 22% made choices consistent with translation invariance (Ballano and Ruiz-Castillo, 1993). There is no evidence, to our knowledge, about such judgments in the context of health inequality. Hence, to the extent that we want to use indices that match societal preferences, we have little empirical basis for choosing between a relative or absolute inequality index.

4.1.1 Indices for bounded health variables

Many health variables of interest are bounded, and so increasingly the Wagstaff and Erreygers indices are being used alongside the standard CI for the evaluation of SES-related health inequality. In our review of empirical papers, 21 out of the 44 studies used either the Wagstaff index, the Erreygers index or both in their assessment of SES-related

[5] The rest of the respondents indicated that their perception of inequality depends on the income levels or none of the options provided appealed to them.

health inequality. When the health variable is bounded uniform changes to the entire health distribution may not be feasible. For a health variable defined over the interval [0,1] with at least some values greater than 0.5, it is not possible to have uniform changes of either 100% or of 0.5 absolute units because in both cases, the changes would extend the value outside the allowable interval of [0,1]. Hence, the Wagstaff and Erreygers indices, which were introduced specifically for bounded health variables, are neither absolute nor relative in the traditional sense because they do not strictly satisfy the properties of scale-invariance or translation invariance (Erreygers and Van Ourti, 2011; Kjellsson and Gerdtham, 2013).[6]

The Wagstaff index was initially proposed as a correction to the standard CI to deal with issues related to the range of the standard CI when the health variable is bounded (Wagstaff, 2005). Wagstaff's correction divides the standard CI by its upper bound, and the resulting index always extends from -1 to +1. The invariance criteria underlying the Wagstaff index—the types of changes to the health distribution that leave measured inequality unchanged—depends on mean health in the distribution (Allanson and Petrie 2014). As the mean level of health, measured in terms of health attainment, tends to zero, the Wagstaff index behaves more like a scale-invariant index. Wagstaff's index is the sum of the absolute magnitude of relative inequality in short-fall and attainment (Kjellsson and Gerdtham, 2013). For example, in Table 2.1 if we add the absolute *magnitude* for

[6] Erreygers and Van Ourti (2011) and Kjellson and Gerdtham (2013) provide a more precise representation of these indices based on how the normalization function reacts to relative and absolute changes, referred to as the elasticity of the normalization function with respect to the mean. The elasticity of the normalization function can be used to determine the indices sensitivity to relative and absolute changes.

attainment inequality and shortfall inequality from the standard CI (short-fall inequality, i.e. standard CI = 0.095; attainment inequality, i.e., standard CI = 0.152), we obtain the estimate observed for the Wagstaff index (0.248). But as we illustrate in Table 2.1, referring to it as a "corrected CI" (as some in the literature do) is misleading since the Wagstaff index behaves differently to the standard CI under various manipulations of the health distribution. For example, an equiproportionate increase of 5% in life expectancy causes an increase in the Wagstaff index while estimates of income-related health inequality remain constant for the standard CI, an equal increment of 5 years in life-expectancy causes an increase in estimates of income-related health inequality for the Wagstaff index but a reduction for the standard CI.

Erreygers' index is translation invariant for feasible uniform changes: equal increments to the health distribution leaves measured inequality unchanged. The Erreygers index is related to the generalized CI through the following rescaling factor: $(4/b_h-a_h)$, where b_h is the upper bound of the health variable and a_h is the lower bound. Hence, this rescaling factor takes into consideration the bounds of the health variable. To illustrate the relationship between the Erreygers Index and the Generalized CI, observe how the point estimate for the Erreygers Index is equal to $(4/b_h-a_h)$*GCI, the point estimate for the generalized CI in distribution 4 of Table 2.1.

In correcting for perceived shortcomings of the standard CI (e.g., non-ratio scaled and bounded health variables), the Wagstaff and Erreygers indices do not maintain the characteristics of the standard CI. These indices have their own unique properties and normative assumptions making them differ from the standard CI in important ways, including the type of changes that reduce SES-related health inequalities, the types of changes that do not result in changes in inequality (the invariance axiom assumed), and the definition of the most unequal society. Our review of the empirical papers found that several studies employing the Wagstaff and/or Erreygers indices refer to these alternative indices as corrections to the standard CI (e.g., Cabieses et al., 2015; Dorjdagva et al., 2015; King et al., 2015; Siegel et al., 2015) and others refer to them simply as the concentration index (e.g., Hudson et al., 2015; Mosquera et al., 2016). Referring to these indices as the CI or corrections to the CI gives the erroneous impression that these alternative indices retain the properties and therefore normative assumptions underlying the standard CI. Moreover, several studies compare estimates of SES-related health inequality from these alternative indices to estimates from the standard CI, either within the same study or in reference to other studies in the literature. Such comparisons are confusing since the alternative indices to the standard CI, (including but not limited to the Wagstaff and Erreygers index) are not equivalent and therefore changes or differences in estimates of SES-related health inequality cannot be directly compared.

4.1.2 Doubly bounded variables and the mirror property

For doubly bounded health variables (i.e., Health Utilities Index, presence or absence of an illness), some indices are sensitive to whether health is measured in terms of attainment or shortfall. That is, for the same underlying distribution of health, a relative index like the standard CI will provide a quantitatively different estimate of SES-related health inequality when inequality is measured in terms of attainment (e.g., distribution 1 in Table 2.1 reports 0.095 for distribution of health) rather than shortfall (e.g., distribution 4 in Table 2.1 reports -0.152 for the distribution of ill-health). As a result, ranking of health distributions may also depend on the chosen perspective (Clarke et al., 2002; Erreygers et al., 2012). This has led some (e.g., Erreygers et al., 2012) to argue that indices used for bivariate health inequality measurement should satisfy the 'mirror property': whether a doubly bounded health variable is measured as attainment or shortfall, a bi-variate index should have the same magnitude but opposite sign. In Table 2.1, for instance, values of the generalized concentration index, the Wagstaff index and the Erreygers index are the same magnitude but of different sign for distributions 1 and 4.

The mirror property has important implications for the relative or absolute nature of an index. In general, absolute indices (e.g., the generalized concentration index) satisfy the mirror property while relative indices (e.g., standard CI) satisfy the mirror property only in the special case when health and ill-health have the same mean (Allanson and Petrie, 2014; Lambert and Zheng, 2011). The Wagstaff and Erreygers indices, which are of mixed type, also satisfy the mirror property.

There remains debate about whether an index satisfying the mirror property should always be used with bounded health variables. This choice likely depends on the context under study and consideration of the indices other properties, see Kjellsson et al., (2015). Normatively, however, choosing to use an index that satisfies the mirror property implies that the analyst can choose whether health and ill-health should be viewed as equivalent.

4.2 Changes to subgroups in the population and the weighting function

As discussed above, the CI-based indices are a weighted sum of h_i, the heath outcome of interest, across all individuals in the population. The weight assigned to an individual, z_i, depends on the individual's rank in the population with respect to their SES status. The impact on measured SES-related inequality of changes in health among a subset of individuals in the population depends on two things: (1) where in the SES distribution the changes in health occur, e.g., only among those with low SES status, only those with high SES status, or a mixture; and (2) the weights assigned to those individuals whose health has changed. To see why, consider weighting functions for the CI-based indices. Figure 2.3 presents weighting functions for the standard CI, the extended CI, and the Symmetric index.[7] For the standard CI, the weight assigned to the individual with the lowest SES status is 2.0, and the weights decrease linearly as rank increases, ultimately reaching a value of 0 for the highest SES-ranked individual. The decreasing pattern of weights reflects an aversion to SES-related inequality such that the value of the index is more

[7] Figure 2.3 presents the absolute value of the weights. However, those at the lower-end of the SES-distribution will have negative weights and those at the upper-end positive weights. For example, for the standard CI and the symmetric index, those above the median have positive weights and those below the median have negative weights. For the extended CI, the point at which the weights turn from positive to negative can be determined by the individual whose fractional rank $p= 1-(1/v)^{(1/(v-1)}$, where v equals the inequality aversion parameter. This mixture of negative and positive weights generates the negative values for an index when a distribution is pro-poor and positive values for an index when a distribution is pro-rich.

sensitive to changes in health among those with lower-SES than it is among those with higher SES: if the health of a rich person declines and that of a poor person improves by *the same amount*, the change in health for the poor person will receive greater weight, causing measured inequality to decrease if the distribution is pro-rich and increase if the distribution is pro-poor. Comparing the index values for distributions 1 and 5 in Table 2.1, for example, shows that when life expectancy for the richest individual decreased by 3 years and life- expectancy for poorest increased by 3 years, inequality decreased for all the indices.

A key property of the extended CI is that it allows one to specify the value of the inequality aversion parameter, which reflects the assumed extent to which society dislikes inequality. Figure 2.3 presents the weighting function for the extended CI under two assumed values of the inequality aversion parameter ($v = 3$ and $v = 4$, where the higher value indicates stronger aversion). We can see that, compared to the standard CI, which assumes a value of $v = 2$, the difference in weights between poor and rich is larger, just as the values differ more when $v = 4$ than when $v = 3$. As a result, as shown in Table 2.1, the estimates for the extended CI with an inequality aversion parameter of 3 are consistently larger than estimates obtained for the standard CI. The weighting function for the Symmetric index follows a quite different pattern: its U-shape gives greater weight to individuals at both ends of the SES distribution in a symmetric manner. For the symmetric index, what matters is how far a person is from the centre of the SES-distribution, so, for instance, a person with low income rank and good health doesn't count any more than does a person with a high income rank but poor health (Erreygers et al., 2012). In viewing deviations from equality among the rich and the poor equally, the symmetric index is an alternative way of looking at systematic associations between SES and health.

4.2.1 Transfers

The effect on inequality of transfers of the outcome of interest among individuals in the population has been a central issue in inequality measurement. The notion of transfers among individuals is natural for income, and a key axiom underlying income inequality measurement has been the transfer principle (Dalton, 1925; Pigou, 1912): a transfer of income from a richer person to a poorer person decreases income inequality (Clark and D'Ambrosio, 2014; Cowell 2000). By construction, all univariate rank dependent indices satisfy this transfer principle, and the extent to which transfers reduce inequality depends on the weighting function. The issue of transfers is more complicated in the context of the measurement of SES-related health inequality (Bleichrodt and van Doorslaer, 2006; Fleurbaey and Schokkaert, 2011). In this bi-variate context, the CI-based indices all conform to the principle of income-related health transfers, which holds that transfers of health from someone who is better-off in terms of socio-economic status to someone who is worse-off decreases SES-related health inequality.

Unlike income, health cannot be directly transferred between two people. It is possible, however, to "transfer" health among groups over time by selective investments in improving health for certain groups of the population. Hence, considerations of transfers are relevant to health distributions, however, the transfer principle raises new ethical issues for bi-variate SES health inequality measurement. A transfer of health from a richer person to a poorer person may be objectionable if the richer person is in bad health and the poorer person is in good health (Bleichrodt and van Doorslaer, 2006; Fleurbaey and Schokkaert, 2011). Indeed, the limited empirical evidence available indicates that the public may not support transfers of health from someone who is better-off in terms of socio-economic status to someone who is worse-off (Bleichrodt et al., 2012). Similarly, society may also object to policies that lower the health of some people to create a more equal distribution, a view illustrated in how some empirical papers interpret their index estimates. Walsh and Cullinan, (2015), for example, state "a redistribution of approximately 16.8% of the obesity rate from the poorest half of the income distribution to the richest half would result in perfect equality in the prevalence of childhood obesity," and then claim, "Obviously a reduction in the overall rate of obesity, rather than this redistribution, would be preferable." (page 67).

The relevance of the transfer principle in the bivariate health-SES context is therefore contestable if health transfers are considered ethically objectionable. This contrasts with the limited empirical evidence on income inequality that indicates some support from the public for income transfers from the rich to the poor (Amiel and Cowell, 1999; Cowell et al., 2015). It is unclear what the transfer principle underlying the CI-based indices should be replaced with as there is no clear alternative assumption.

5.0 What do the estimates of inequality mean and when are they of policy concern?

In this section we consider two main issues: 1) that indices encompass information about an entire distribution in a single number; and 2) the challenge of determining if index estimates are large and of policy significance. As has been emphasized, the CI-based indices differ in important ways, which can make it challenging to interpret and compare estimates of income-related health inequality, especially across indices. For example, the underlying scale on which income-related health inequality is measured can differ because the variants of the CI have different normalization functions (as shown in Table 2.1). As emphasized, the range of possible values even for the *same* index can differ when an index is applied to countries or time periods with differing average levels of health in the population. Further, one must be careful when interpreting the magnitude of an index estimate: a low estimate of SES-related health inequality can be generated by very little SES-related health inequality, or by large but off-setting SES-related inequality at different parts of the SES distribution. This can be revealed only by examining the concentration curve(s). In the latter case, the concentration curves will cross the diagonal one or more times. Empirical examples of concentration curves crossing can be found in Buisman and García-Gómez, (2015) and Mosquera et al., (2016). Analogously, the identical estimates of SES-related inequalities across jurisdictions (or time) can be generated by very different patterns of inequality that have different policy implications.

Hence, it is important to examine the concentration curves themselves as part of interpreting the meaning and policy significance of the estimates obtained from the CI-based indices.

The absence of a natural scale for the CI-based indices is a key obstacle to their interpretation, making it difficult to determine whether inequalities are large and of policy concern. This challenge was the impetus for Koolman and van Doorslaer's (2004) redistributive interpretation. Under their redistributive interpretation, multiplying the standard CI estimate by 75 provides the percentage of the health in the population that must be transferred from the richer to poorer half of the population to arrive at an index estimate of zero. This is an approximation, and while intuitive in some ways, is subject to the same challenges noted above for interpreting point estimates (i.e., when concentration curves cross the line of equality). Moreover, Koolman and van Doorslaer's (2004) redistributive interpretation is based on a very specific notion of redistribution that conforms to the weighting scheme underlying the standard CI: the interpretation applies to the standard CI only and is not valid for other variants without a reformulation.

The difficulty in providing an intuitive interpretation when the index estimates lack a natural scale is reflected in how empirical papers using the CI-based indices report their findings. The vast majority of studies in our review (38 out of 44) describe the estimates of the indices in terms of their direction (whether inequalities are pro-poor or pro-rich), without elaborating on the magnitudes of the index estimates. Three studies use Koolman and van Doorslaers' (2004) redistributive interpretation to describe the index estimates. However, in all three studies a variant of the CI was used rather than the standard CI. Therefore, the validity of the interpretation is unclear. Three studies presented the point estimates of SES-related health inequality alongside the feasible bounds of the index when the outcome variable was bounded. However, several studies (n=14) using bounded outcome variables and comparing inequalities across jurisdictions, time periods, or both did not provide the feasible bounds of the index, which made it difficult to interpret differences or changes in the estimates since the bounds of the index could vary. Moreover, some studies describe the magnitudes using terms like 'modest', 'large', 'pronounced', and 'high' (e.g., Devkota and Upadhyay, 2015; Laskowska, 2015; Xu et al., 2015; Zhang et al., 2015), however the criteria used for classifying estimates into these categories was not stated.

To move from inequality estimates to policy we need to understand what is driving the estimate. One of the purported advantages of the CI-based indices is that the indices provide a single summary estimate of income-related health inequality, which many assume is directly comparable across jurisdictions and time. But to make sense of this single estimate and to assess its potential implications requires a broader array of information. For example, as shown in Koolman and van Doorslaer (2004), the same association, or strength of the correlation, between income and health can result in different inequalities depending on the variability of health in the population. Since the CI-based indices capture the correlation of health with rank in the SES distribution, as well as inequality in health, whether an estimate is large or concerning can be better assessed through the use of additional information such as concentration curves, the minimum and maximum range of the index, the correlation coefficient between health and income, and/or the coefficient of variation in health. Less than half (19 of 44) of the empirical papers we reviewed presented concentration curves and only 3 studies presented the minimum and maximum range of the index.

To better understand the sources of inequality, several studies (31 out of 44) decomposed the estimates into their contributing parts. Such decompositions, however, are purely descriptive (based on correlations) and so do not support causal interpretations. Nonetheless, 23 of the 31 studies that performed decompositions translated them into policy recommendations on the assumption that the factors with the largest contribution to the index should be the focus of policy action. Although beyond the scope of this paper, a number of other issue arise with decompositions. The dominant decomposition technique proposed by Wagstaff et al., (2003) has been criticized for two shortcomings in the bivariate health context. First, that it is uni-dimensional, focusing on health rather than the joint distribution of health with SES. Second, the estimates are difficult to interpret. Kessels and Erreygers (2016) propose an alternative approach that incorporates the joint distribution of health with SES into the decomposition analysis, and Heckley et al., (2016) propose a different approach using the concept of a regression of a re-centered influence function (RIF).

Presenting a single summary number is valuable, but providing this information alone is insufficient for understanding SES-related health inequalities and for providing policy recommendations. Perhaps more importantly, policy recommendations on reducing SES-related health inequalities are valid only once the causes driving the inequalities are understood. The CI-based indices, however, are descriptive tools.

6.0 Choosing among the indices and concluding remarks

The increased policy focus on health inequalities requires that we have measurement tools that allow us to monitor differences and changes in socio-economic-related health inequalities consistently and accurately (see for e.g., Canadian Institute for Health Information, 2016; OECD, 2011). However, the different estimates of SES-related health inequality obtained by the CI-based indices reflect different normative judgments about SES-related health inequality. Notions of accuracy in terms of how well the indices reflect the extent of SES-related health inequality present in a distribution(s) are therefore conditional on a series of value-laden assumptions. The diversity in the potential conclusions and the inconsistencies in ranking are not necessarily incorrect, but reflect alternative perspectives of SES-related health inequality. To the extent possible, analysts should choose measure(s) that adequately capture the values of society. If this is not feasible, these normative assumptions should be made more explicit for policy-makers so that they can determine whether the normative assumptions are appropriate for the context under study. As argued in Kjellsson et al., (2015), due to the diversity in potential conclusions one can obtain from the CI-based indices, there is an increased risk that analysts present the measure that best supports their chosen conclusion. This risk is mitigated if the implicit value judgments are made explicit. In Table 2.2 we provide a succinct summary of the CI-based indices, including their technical properties and normative assumptions.

To make an informed choice of an index, the analyst should ask a series of questions. Figure 2.4 displays a flow chart of critical questions. First, what are the properties of the health variable for which inequalities will be assessed? The informational content of the health variable of interest determines which of the indices *can* be used e.g. a scale-invariant index cannot be used with interval scaled health variables. Second, what kind of changes to the distribution of health should leave measured inequality unchanged from its initial value? Considering the invariance criteria ensures that there is a match of technical properties *and* normative judgments. Third, if the health variable is bounded, is the mirror property relevant for the context under study? For the mirror property, in some instances, the ill-health version may be more informative to policy-makers than its complement, for example, the socioeconomic status association between premature mortality from a specific cause (e.g., death from opioids) may be more informative in monitoring the effects of a policy than simply focusing on life-expectancy. Importantly, for relative indices an equiproportionate change in attainments will not necessarily constitute an equiproportionate change in shortfalls and vice versa. And fourth, does the underlying weighting scheme adequately captures who matters and by how much? Choosing a symmetric versus an asymmetric weighting scheme will weigh members of society differently which in turn will affect the ranking of distributions of SES- related health inequality, as shown in Erreygers, Clarke, and Van Ourti (2012). One approach to choosing an appropriate weighting function is to choose weights based on social preferences for the context under study, for example, society's inequality aversion preferences.

These questions may not result in a perfect match between the health variable and index. However, these series of questions may facilitate further sensitivity tests and help provide a better understanding of the index estimates. Because no index is value-neutral, the chosen index should be consistent with the measurement process, the context of the study, and the goal of the analysis.

In the last two decades a variety of policies, programs and interventions have been implemented in response to empirical findings on the social gradient in health (Devaux, 2015). However, our assessments of the magnitude and trends depend in part on the indices we choose to measure inequalities with. For example, the choice between a relative and absolute index will affect conclusions on whether policies or programs intended on reducing SES-related inequalities are successful since reducing absolute inequalities are much more difficult than reducing relative inequalities (Wagstaff, 2015). When inequality measurement begins to be viewed not as objective fact, but objective facts conditional on a series of normative conditions, we can have a greater understanding of what we are measuring and reduce misinterpretation of the evidence presented as part of the debate, all of which will lead to better assessments of SES-related health inequalities.

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Tables and Figures

Table 2.1 Estimates of income-related health inequality for the CI-based indices under various changes to the health distribution

Individuals (i) n = 5	Income (dollars)	1) Baseline Life Expectancy (LE)	2) 5% increase in LE	3) Increase of 5yrs to LE	4) Ill-Health (assume max LE of 120)	5) Transfer of LE
1	20,000	59	61.95	64	61	59+3 → **62**
2	30,000	63	66.15	68	57	63
3	58,000	70	73.50	75	50	70
4	74,000	85	89.25	90	35	85
5	100,000	92	96.60	97	28	92-3→ **89**
Mean	56,400	73.80	77.49	78.80	46.20	73.80
Standard CI Point estimate (Index Bounds)		0.095 (-0.800, +0.800)	0.095 (-0.800, +0.800)	0.089 (-0.800, +0.800)	-0.152 (-0.385, +0.385)	0.082 (-0.800, +0.800)
Generalized CI Point Estimate (Index Bounds)		7.040 (-59.040, +59.040)	7.392 (-61.992, +61.992)	7.040 (-63.040,+63.040)	-7.04 (-36.960, +36.960)	6.080 (-59.040, +59.040)
Extended CI, with Inequality aversion = 3 (Index Bounds)		0.139 (-1.430, +0.970)	0.139 (-1.430, +0.970)	0.130 (-1.430, +0.970)	-0.221	0.119 (-1.430, +0.970)
Symmetric Index, with Inequality aversion = 3 (Index Bounds)		0.103 (-1.50, +1.50)	0.103 (-1.50, +1.50)	0.097 (-1.50, +1.50)	-0.165	0.087 (-1.50, +1.50)
Wagstaff Index Point Estimate (Index Bounds) *assume max LE of 120 yrs.		0.248 (-1.00, +1.00)	0.269 (-1.00, +1.00)	0.260 (-1.00, +1.00)	-0.248 (-1.00, +1.00)	0.214 (-1.00, +1.00)
Erreygers Index Point Estimate (Index Bounds) *assume max LE of 120 yrs.		0.235 (-0.947, +0.947)	0.246 (-0.915, +0.915)	0.235 (-0.902, +0.902)	-0.235 (-0.947, +0.947)	0.203 (-0.947, +0.947

Notes: The Wagstaff and Erreygers indices can only be used with bounded health variables. Point estimates were calculated using ‘conindex’ STATA package. Numbers rounded to three decimal places.

Table 2.2 Summary of CI-based index properties and their health variable requirements

	Properties of the Health Variable (h_i)				Properties of the Index							
	Interval[a]	Ratio	Unbounded	Bounded	Absolute	Relative	Mixed	Mirror	Transfer	Weighting Scheme	Index Equation	Minimum and Maximum range
Standard CI		✓	✓			✓			✓	Fixed. Inequality aversion parameter (v) =2	$\frac{1}{n}\sum_{i=1}^{n}\left\{\frac{h_i}{\bar{h}}(2R_i\text{-}1)\right\}$	h_i unbounded: $-\frac{(n\text{-}1)}{n}, +\frac{(n\text{-}1)}{n}$ h_i bounded: $-\frac{\mu_h\text{-}a_h}{b_{h-a_h}}, +\frac{\mu_h\text{-}a_h}{b_{h-a_h}}$
Modified CI**	✓		✓			✓			✓	Inequality aversion parameter (v) =2	$\frac{1}{n}\sum_{i=1}^{n}\left\{\frac{h_i}{\bar{h}\text{-}a_h}(2R_i-1)\right\}$	$-\frac{(n\text{-}1)}{n}, +\frac{(n\text{-}1)}{n}$
Generalized CI	✓	✓	✓		✓			✓	✓	Inequality aversion parameter (v) =2	$\frac{1}{n}\sum_{i=1}^{n}\{h_i(2R_i-1)\}$	$\mu_h\frac{(1-n)}{n},\ \mu_h\frac{(n\text{-}1)}{n}$
Extended CI		✓	✓			✓			✓	Asymmetric Inequality aversion parameter (v) can be varied	$\frac{1}{n}\sum_{i=1}^{n}\left[\frac{h_i}{\bar{h}}\{1-v(1-R_i)^{v-1}\}\right]$	$1-v\left(\frac{2n\text{-}1}{2n}\right)^{v\text{-}1}$, $1-v\left(\frac{1}{2n}\right)^{v\text{-}1}$
Generalized Extended CI	✓	✓	✓	✓	✓			✓	✓	Inequality aversion parameter (v) can be varied	$\frac{1}{n}\sum_{i=1}^{n}[h_i\{1-v(1-R_i)^{v-1}\}]$	$\frac{\nu^{\frac{\nu}{\nu\text{-}1}}}{\nu\text{-}1}(1-\mu_h)[(1-\mu_h)^{\nu-1}]$, $\frac{\nu^{\frac{\nu}{\nu\text{-}1}}}{\nu\text{-}1}\mu_h(1-\mu_h{}^{\nu-1})$
Wagstaff Index	✓	✓		✓			✓≀	✓	✓	Fixed	$\frac{1}{n}\sum_{i=1}^{n}\left[h_i\left\{\frac{h_i}{(1-\bar{h})}\right\}\bar{h}(2R_i-1)\right]$	(-1, +1)
Erreygers Index	✓	✓		✓*			✓T	✓	✓	Fixed	$\frac{1}{n}\sum_{i=1}^{n}\{4h_i(2R_i-1)\}$	$-\frac{4(b_h\text{-}\mu_h)(\mu_h\text{-}a_h)}{(b_h\text{-}a_h)^2}$, $+\frac{4(b_h\text{-}\mu_h)(\mu_h\text{-}a_h)}{(b_h\text{-}a_h)^2}$
Symmetric Index		✓	✓			✓			✓*	Symmetric Inequality aversion parameter (β) can be	$\frac{1}{n}\sum_{i=1}^{n}\left(\frac{h_i}{\bar{h}}\right)\left[\beta 2^{\beta\text{-}2}\left\{\left(R_i\text{-}\frac{1}{2}\right)^2\right\}^{\frac{\beta\text{-}2}{2}}\left(R_i\text{-}\frac{1}{2}\right)\right]$	$-\frac{\beta}{2}$ & $+\frac{\beta}{2}$

										varied β can be varied		
Generalized Symmetric Index	✓	✓	✓	✓	✓			✓	✓*	Symmetric Inequality aversion parameter (β) can be varied β can be varied	$\frac{1}{n}\sum_{i=1}^{n} h_i \left[\beta 2^{\beta-2} \left\{\left(R_i - \frac{1}{2}\right)^2\right\}^{\frac{\beta-2}{2}} \left(R_i - \frac{1}{2}\right)\right]$	$-1 + 2^{\beta}\left[\left(\frac{1}{2} - \mu_h\right)^2\right]^{\frac{\beta}{2}}$, $1 - 2^{\beta}\left[\left(\frac{1}{2} - \mu_h\right)^2\right]^{\frac{\beta}{2}}$

Notes: R_i is the rank of the *i*th person in the SES distribution [*]The range of the index will depend on the mean of the bounded health variable. [a]Except for Erreygers index where measurement scale does not matter, h_i should be measured in same unit to ensure differences in estimates are not reflective of arbitrary differences in measurement unit i.e. weight measured in same units (kg) for all observations. ** h_i is standardized ($h_i \equiv (hi - a)(b - a)$ where $a \leq h_i \leq b$. ⁺quasi relative: index is insensitive to any feasible proportional changes of the standardized health levels (taking into account only relative positions of individuals not absolute difference (Erreygers and Van Ourti 2011).ᵀquasi absolute: level independence of the standardized variable ((Erreygers and Van Ourti 2011). ˀinverse relative: increasing in magnitude when a change occurs which leaves all absolute differences the same and decreases all relative differences (Erreygers and Van Ourti 2011) ν =2 gives standard CI and β=2 gives extended CI ν =2 which is also equivalent to standard CI τ changes at the extreme receive greater weight compared to those in the middle of the socioeconomic distribution

Figure 2.1 Concentration curves for three hypothetical populations

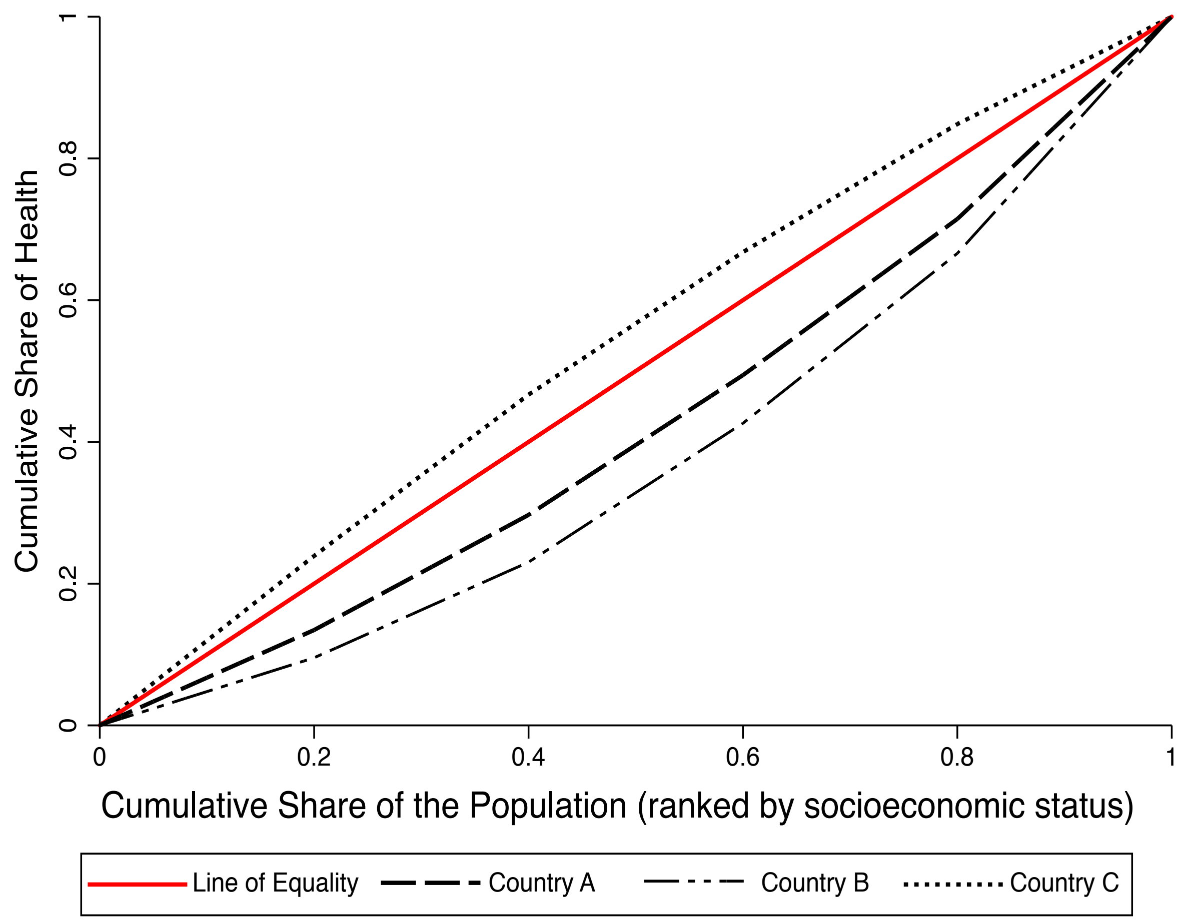
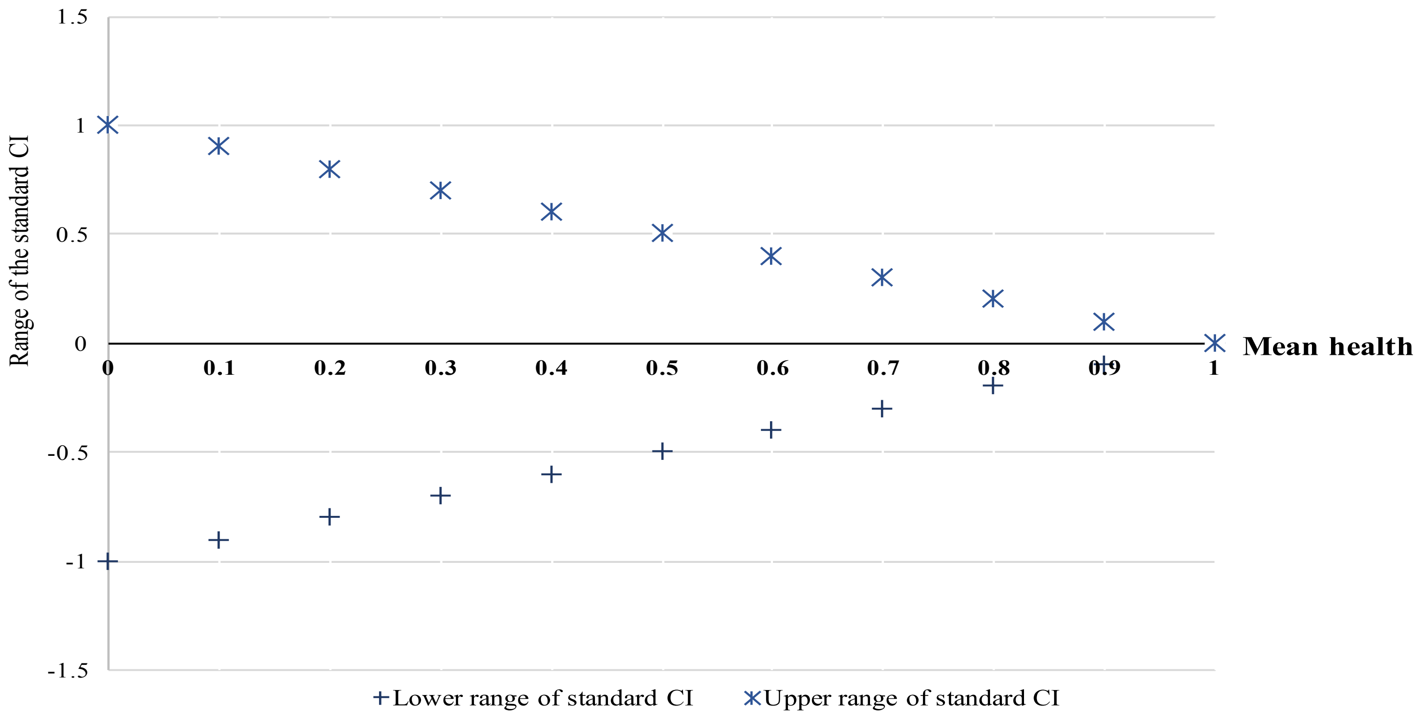
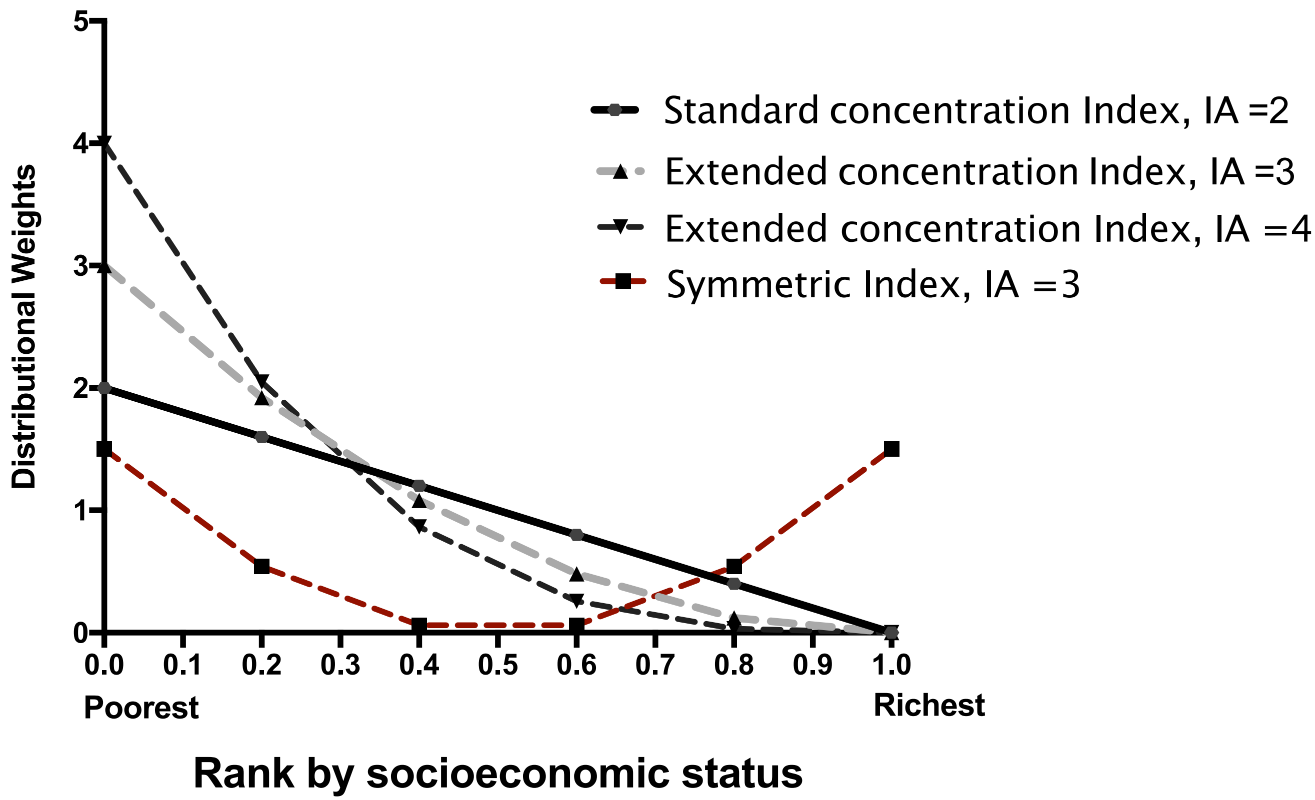


Figure 2.2 The lower and upper bounds of the standard CI for a dichotomous (0,1) outcome variable



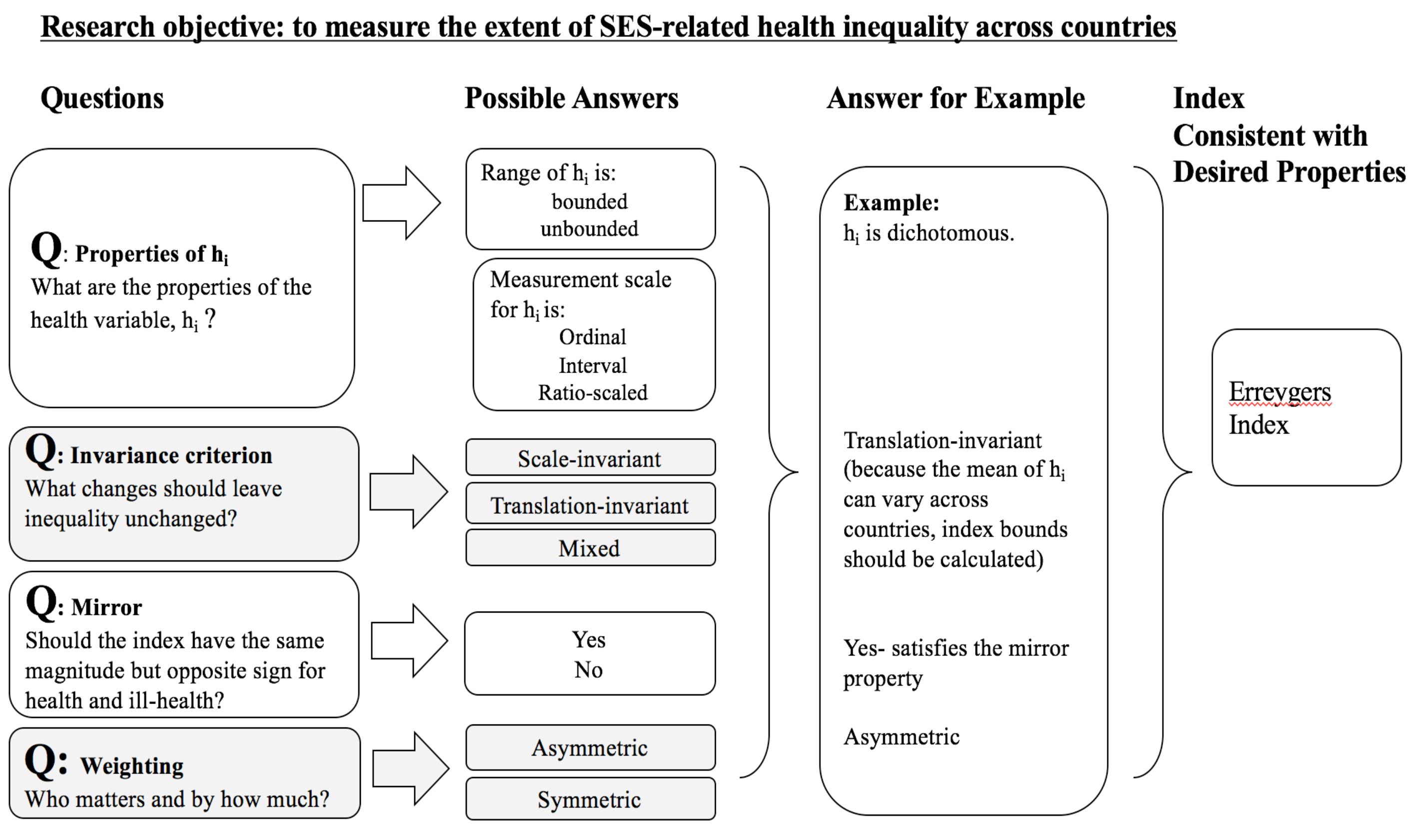
Adapted from Wagstaff, A., 2005. The Bounds of the Concentration Index When the Variable of Interest is Binary, with an Application to Immunization Inequality. Health Econ. 14, 429–432.

Figure 2.3 Distributional weights by rank in the socioeconomic status distribution



IA = Inequality Aversion

Figure 2.4 A flowchart of questions for choosing among the CI-based indices



Appendix 2.1 Table 1 Summary of studies using the CI-based indices published between 2015 and 2017 (inclusive)

Study	h_i (measurement scale)	Concentration curve illustrated	Index Used	Match between index and health measure?	Range of index considered?	Interpretation of Results	Policy prescription provided?	Estimates decomposed
Dorjdagva et al., (2015)	Self-assessed presence of a chronic illness (dichotomous); Self-assessed presence of a physical disability (dichotomous)	No	Erreygers index (referred as correction to CI)	Yes	Yes, Erreygers index used to accommodate bounded outcome variable. Authors awknowledge varying range when mean health varies. Range of index not provided.	Direction: pro-rich/ pro poor.	Yes	Yes
Capurro et al., (2015)	Presence of untreated caries (dichotomous)	Yes	Standard concentra tion index as relative measure; Slope index of inequality for absolute measure	No Mean health varies across the time periods examined making it difficult to interpret changes in inequalities since the range of the index would vary.	Range of index not provided.	As percentage increase in inequality.	No	No
	Reporting	Yes	Standard	Yes	Range of index	Direction: pro-	Yes	Yes

Joe et al., (2015)	health care utilization (dichotomous)		concentra tion index		not provided.	rich/ pro poor.		
Hwang et al., (2015)	Self- reported visual impairments among those with diabetes (dichotomous)	Yes	Standard concentra tion index	Yes	Range of index not provided.	Direction: pro-rich/ pro poor.	Yes	Yes
Devaux, (2015)	General practitioner visits (dichotomous); Specialist visits (dichotomous); Dentist visits (dichotomous); Breast and cervical cancer screening (dichotomous)	No	Wagstaff index	Yes	Yes, Wagstaff index used to accommodate bounded outcome variable. Authors awknowledge varying range when mean health varies.	Direction: pro-rich/ pro poor.	No	No
Walsh and Cullinan, (2015)	Obese (dichotomous); Overweight (dichotomous)	Yes	Wagstaff index	Yes	Yes, Wagstaff index used to accommodate bounded outcome variable. Authors awknowledge varying range when mean health varies.	Interpret using Koolman and van Doorslaer (2004), interpretation on how much to be transferred to poorest half. Unclear whether this interpretation is appropriate for Wagstaff index. Indicates that	No	Yes

						inequalities are large.		
Ataguba et al., (2015)	Self-assessed good health as excellent, very good, or good (dichotomous)	No	Standard concentra tion index	Yes	Range of index not provided.	Direction: pro-rich/ pro poor.	Yes	Yes
Devkota and Upadhyay, (2015)	Probability of physician visit (dichotomous); Number of physician visits (ratio scale)	No	Standard concentra tion index	No Mean health varies across different the countries for probability of physician visit making it difficult to interpret changes in inequalities since the range of the index would vary.	Range of index not provided.	Direction: pro-rich/ pro poor.	Yes	Yes

Laskowska, (2015)	Use of medical service (dichotomous); Visits to a general practitioner (dichotomous); Visits to specialist (dichotomous); Hospital stay (dichotomous)	No	Standard concentration index	No Mean health varies across the different regions examined making it difficult to interpret changes in inequalities since the range of the index would vary.	Range of index not provided.	Direction: pro-rich/ pro poor.	No	No
Buisman and García-Gómez, (2015)	Inpatient hospital use (dichotomous)	Yes	Standard concentration index	Yes	Range of index not provided.	Direction: pro-rich/ pro poor.	Yes	Yes
Zhang et al., (2015)	Doctor visits (dichotomous); Inpatient care (dichotomous)	No	Standard concentration index	Yes	Range of index not provided.	Direction: pro-rich/ pro poor.	Yes	Yes
Raittio et al., (2015)	Toothache or oral discomfort (dichotomous); Perceived current need for dental care (dichotomous); Self reported oral health status	No	Standard concentration index (as relative measure); Erreygers index (as absolute measure)	No Mean health varies across the time periods examined making it difficult to compare inequalities	Range of index not provided.	Direction: pro-rich/ pro poor.	No	Yes

	(dichotomous)			for the standard CI since the range of the index would vary.				
Peres et al., (2015)	Inadequate dentition defined as fewer than 21 natural teeth (dichotomous)	Yes	Standard concentra tion index; Generaliz ed concentra tion index	No Mean health varies across the time period and countries examined making it difficult to interpret changes in inequalities for the standard CI since the range of the index would vary.	Range of index not provided.	Whether inequalities increased or decreased over time	No	No
Layte and Nolan, (2015)	General practitioner utilization (dichotomous); Number of general practitioner visits (ratio scale); Birth weight (ratio-scale); Gestation	No	Standard concentra tion index (for ratio scale variables) ; Erreygers index (for dichotom ous variables)	Yes	Yes, Erreygers index used to accommodate bounded outcome variable. Authors awknowledge varying range when mean health varies.	Direction: pro-rich/ pro poor. Results from the different indices compared as if equivalent.	No	Yes

	(ratio-scale); Parental-assessed health (dichotomous); Presence of an accident (dichotomous)				Range of index not provided.			
Hudson et al., (2015)	Smoking status (dichotomous); Frequent alcohol consumption defined as 5-7 days per week (dichotomous); Low physical activity (dichotomous)	No	Erreygers index (labelled as concentra tion index);	Yes	Yes, Erreygers index used to accommodate bounded outcome variable. Authors awknowledge varying range when mean health varies. Range of index not provided.	Interpret using Koolman and van Doorslaer (2004), interpretation on how much to be transferred to poorest half. Unclear whether this interpretation is appropriate for Erreygers index.	No	Yes
King et al., (2015)	Avoidable mortality (dichotomous); Amenable mortality (dichotomous); Preventable mortality (dichotomous)	No	Erreygers index (Referred to as corrected CI); Standard concentra tion index	No for standard CI. Mean health varies across the time periods examined making it difficult to interpret changes in inequalities for the standard CI since the range of the	Yes, Erreygers index used to accommodate bounded outcome variable. Authors awknowledge varying range when mean health varies. Range of index not provided.	Direction: pro-rich/ pro poor.	Yes	No

				index would vary.				
Xu et al., (2015)	Whether household incurred castastrophich health expenditure (dichotomous)	Yes	Standard concentra tion index	No Mean health varies across the time periods examined making it difficult to interpret changes in inequalities for the standard CI since the range of the index would vary.	Range of index not provided.	Direction: pro-rich/ pro poor.	Yes	Yes
Cabieses et al., (2015)	Self-reported health status (dichotomous)	Yes	Erreygers index (referred as corrected CI); Standard concentra tion index (to compare):	Yes for Erreygers index. No for standard CI since mean health varies for boys and girls making it difficult to compare inequalities	Range of index not provided.	Direction: pro-rich/ pro poor. Noted: "Since concentration indices can be hard for policy makers to interpret, we also perform a simpler analysis based on more intuitive ratio and pag	No	Yes

				for the standard CI since the range of the index would vary.		measures of inequality"		
Pal, (2015)	Receipt of full antenatal care (dichotomous); Institutional or home delivery attended by skilled health professional (dichotomous)	Yes	Standard concentra tion index	Yes	Range of index not provided.	Not provided focus on interpreting decomposition analysis	Yes	Yes
Siegel et al., (2015)	BMI 30 or higher (dichotomous); Self-reported hypertension (dichotomous); Self-reported diabetes (dichotomous)	No	Wagstaff index (referred to as corrected CI)	Yes	Yes, Wagstaff index used to accommodate bounded outcome variable. Authors awknowledge varying range when mean health varies.	Direction: pro-rich/ pro poor.	No	No

Mosquera et al., (2016)	CVD events defined as first time hospitalizations with main diagnosis of circulatory diagnosis (dichotomous)	Yes	Wagstaff index (Referred to as concentration index)	Yes	Yes, Wagstaff index used to accommodate bounded outcome variable. Authors awknowledge varying range when mean health varies.	Direction: pro-rich/ pro poor. In relation to concentration curve.	No	Yes
Sözmen and Ünal, (2016)	General practitioner visits (dichotomous); Specialist visit (dichotomous); Inpatient care (dichotomous); Dental care (dichotomous); Emergency care (dichotomous); Number of general practitioner visits (ratio scale); Number of specialist practitioner visits (ratio scale); Number of	Yes	Standard concentration index (for ratio scale variables); Wagstaff index (for dichotomous variables)	Yes	Yes, Wagstaff index used to accommodate bounded outcome variable. Authors awknowledge varying range when mean health varies.	Direction: pro-rich/ pro poor. Compared estimates of standard CI to Wagstaff index as if they are equivalent.	No	Yes

	inpatient visits (ratio scale); Number of denal visits (ratio scale); Number of emergency visits (ratio scale);							
Murakami and Hashimoto, (2016)	Self reported dental care use (dichotomous)	No	Standard concentration index	Yes	Range of index not provided	Direction: pro-rich/ pro poor.	Yes	No
Walsh et al., (2016)	Up to date vaccination uptake (dichotomous); Vaccination usage – diphtheria-tetanus, acellular pertussis, measles-mumps-rubella and polio (dichotomous)	Yes	Wagstaff index	Yes	Yes, Wagstaff index used to accommodate bounded outcome variable. Authors awknowledge varying range when mean health varies.	Direction: pro-rich/ pro poor. Also provide Koolman and van Doorslaer (2004), interpretation on how much to be transferred to poorest half. Unclear whether this interpretation is appropriate for Wagstaff index.	No	No
Kim and Hwang, (2016)	Self report gastric/colorectal cancer screening services (dichotomous)	No	Wagstaff index (referred to as renormalization of standard CI)	Yes	Yes, Wagstaff index used to accommodate bounded outcome variable. Authors awknowledge varying range	Direction: pro-rich/ pro poor.	Yes	Yes

					when mean health varies.			
Ma et al., (2016)	Whether household incurred castastrophich health expenditure (dichotomous)	No	Standard concentra tion index	No Mean health varies across the three provinces examined making it difficult to compare inequalities for the standard CI since the range of the index would vary.	Range of index not provided	Discussed trends in standard concentration index	Yes	No
Gonzalo-almorox and Urbanos-garrido, (2016)	No physical activity versus some physical activity (dichotomous)	No	Erreygers index; Standard concentra tion index	Yes for Erreygers index. No for standard CI since mean health varies for boys and girls making it difficult	Yes, Erreygers index used to accommodate bounded outcome variable. Authors awknowledge varying range when mean health varies.	Direction: pro-rich/ pro poor .	Yes	Yes

				to compare inequalities for the standard CI since the range of the index would vary. Range of index not provided	Range of index not provided.			
Shao et al., (2016)	Ill-health score constructed using self-rated health (unclear)	Yes	Standard concentra tion index	Unclear	Range of index not provided.	Direction: pro-rich/ pro poor.	Yes	Yes
Davillas and Benzeval, (2016)	BMI (ratio-scale, bounded); BMI components-total body fat (ratio-scale, bounded); BMI components-fat free mass (ratio-scale, bounded); Percent body fat (ratio-scale); Waist circumference (ratio-scale, bounded);	No	Erreygers index; Wagstaff index (sensitivit y analysis)	Yes	Yes, Erreygers and Wagstaff index used to accommodate bounded outcome variable. Authors awknowledge varying range when mean health varies. Range of index not provided for Erreygers	Direction: pro-rich/ pro poor.	No	Yes

	Obesity based on BMI where BMI >30 (dichotomous); Where percent body fat > 25 males and >32 females (dichotomous); Obese Gallanger-percent body fat (dichotomous); Abdominal obesity where waist circumference greater than 102 cm males and 88 cm females (dichotomous)							
Zhang et al., (2016)	Mortality rate reduction (ratio-scale bounded)	Yes	Standard concentra tion index	No Mean health varies across the time periods examined making it difficult to interpret changes in inequalities for the standard CI since the	Range of index not provided.	Direction: pro-rich/ pro poor.	Yes	No

				range of the index would vary.				
Mullachery et al., (2016)	Self reported doctor visits (dichotomous); Dentist visits (dichotomous); Hospital admission (dichotomous); Reporting of usual source of care (dichotomous)	No	Standard concentra tion index	Yes	Yes bounds calculated but incorrectly (p-1 and 1-p where p is prevalence)	Direction: pro-rich/ pro poor and as a percentage of feasible upper bound	No	Yes
Xu et al., (2016)	Presence of depressive symptoms (dichotomous)	Yes	Standard concentra tion index	Yes	Range of index not provided.	Direction: pro-rich/ pro poor.	Yes	Yes
Carrieri and Jones, (2016)	Use of e-cigs and other nicotine delivery systems (dichotomous)	No	Erreygers index	Yes	Yes Magnitudes described relative to bounds of index (i.e. range of index)	Direction: pro-rich/ pro poor.	No	Yes

Palafox et al., (2016)	Hypertension treatment (dichotomous); Hypertension awareness (dichotomous); Hypertension control (dichotomous)	No	Wagstaff index	Yes	Yes, Wagstaff index used to accommodate bounded outcome variable. Authors awknowledge varying range when mean health varies.	Direction: pro-rich/ pro poor.	No	No
Mukong et al., (2017)	Diagnosed with tuberculosis (dichotomous); Diagnosed with high blood pressure (dichotomous); Diagnosed with stroke (dichotomous); Diagnosed with diabetes (dichotomous); Diagnosed with stroke (dichotomous); Diagnosed with heart problems (dichotomous); Diagnosed with cancer (dichotomous); Persistent cough	No	Erreygers index	Yes	Yes, Erreygers index used to accommodate bounded outcome variable. Authors awknowledge varying range when mean health varies. Range of index not provided.	Direction: pro-rich/ pro poor.	Yes	Yes

	(dichotomous); Experiencing depression (dichotomous); Experiencing chest pain (dichotomous); Using PCA reduced to a single index value for health status (measurement scale unclear); Sensitivity analysis with self-assessed health (dichotomous)							
Si et al., (2017)	Whether household incurred castastrophich health expenditure (dichotomous)	Yes	Standard concentra tion index	No Mean health varies across the sub groups examined making it difficult to interpret differences in inequalities since the range of the standard CI would vary.	Range of index not provided.	Direction: pro-rich/ pro poor.	Yes	Yes

Li et al., 2(017)	Probability of outpatient visits in the last month (dichotomous); Total number of outpatient visits in the last month (ratio-scale); Probability of inpatient visits in the last year (dichotomous); Total number of inpatient visits in the last year (ratio scaled).	No	Standard concentra tion index	Yes	Range of index not provided.	Direction: pro-rich/ pro poor	Yes	Yes
Ásgeirsdóttir and Jóhannsdóttir, (2017)	Eye disease (dichotomous); Irritable bowel syndrome (dichotomous); Chronic fatigue syndrome (dichotomous); Cold/flu (dichotomous); Alcoholism (or substance addiction) (dichotomous); Chronic anxiety (dichotomous);	No	Wagstaff index	Yes	Yes, Wagstaff index used to accommodate bounded outcome variable. Authors awknowledge varying range when mean health varies.	Direction: pro-rich/ pro poor.	No	Yes

	Chronic depression (dichotomous); Anxiety (dichotomous); Serious worries (dichotomous); Sleeping difficulties (dichotomous); other mental disorders (dichotomous); Shortness of breath (dichotomous); Debility (dichotomous); Myalgia (dichotomous); Back/shoulder pain (dichotomous); Arm pain (dichotomous); Leg pain (dichotomous); Frequent headaches (dichotomous); Toothache (dichotomous); Abdominal pain (dichotomous); Rheumatoid							

	arthritis (dichotomous); Osteoarthritis (dichotomous); Fibromyalgia (dichotomous); Chronic back syndrome (dichotomous); Chronic throat disease (dichotomous); Diabetes (dichotomous); Serious headaches (dichotomous); Urinary incontinence (dichotomous); Thyroid disease (dichotomous); High blood pressure (dichotomous)							
Quintal and Oliveira, (2017)	Overweight or obese (dichotomous)	Yes	Wagstaff index	Yes	Yes, Wagstaff index used to accommodate bounded outcome variable. Authors awknowledge varying range when mean health varies.	Direction: pro-rich/ pro poor.	No	No

Zheng et al., (2017)	Hepatitis B awareness ordinal, score ranging from 0-5 (measurement scale unclear)	Yes	Standard concentra tion index	No	Range of index not provided.	Direction: pro-rich/ pro poor.	Yes	Yes
Amroussia et al., (2017)	Mental well-being- good versus poor mental health (dichotomous)	Yes	Wagstaff index	Yes	Yes, Wagstaff index used to accommodate bounded outcome variable. Authors acknowledge varying range when mean health varies.	Direction: pro-rich/ pro poor.	No	Yes
Bilger et al., (2017)	Status- obese or not (dichotomous); Depth - average excess BMI over the obesity threshold (bounded, ratio-scale); Severity of obesity average squared excess (ratio scale)	No	Standard concentra tion index	No Mean health varies across the time periods examined making it difficult to interpret changes in inequalities for the standard CI for the bounded variables since the range of the index would	Range of index not provided.	Direction: pro-rich/ pro poor.	No	Yes

				vary.				
Berke-Berga et al., (2017)	Self-assessed good health (dichotomous)	No	Standard concentra tion index	No Mean health varies across the time periods examined making it difficult to interpret changes in inequalities for the standard CI since the range of the index would vary.	Range of index not provided.	Direction: pro-rich/ pro poor. (referred to as better off and worst off)	No	Yes
Martenies et al., (2017)	Exposure concentrations: $PM_{2.5}$, O_3, SO_2, NO_2 (ratio-scale)	No	Standard concentra tion index	Yes	Range of index not provided.	Direction: less socially advantaged versus more socially advantaged.	No	No

Appendix 2.2 Literature review search strategy

The purpose of the literature review was to identify empirical studies that employ the concentration-based indices to estimate socio-economic related health inequality. This was done to better understand how these indices are currently used. The indices considered include the standard concentration index, extended concentration index, generalized concentration index, modified concentration index, Wagstaff index, Erreygers Index, symmetric index, and generalized symmetric index. The peer-reviewed academic literature from electronic databases was searched between May and September 2018. The search terms included key words such as income related health inequality, socioeconomic health inequality, concentration index, Erreygers index, and Wagstaff index. The databases included Web of Science, EconLit, OVID Medline, EMBASE, CINAHL, PROQuest, and JSTOR. The search was also extended to the references cited in studies, as well as a search of studies citing key references related to methodological papers of CI-based indices. The search strategy was restricted to empirical studies published in the English language and in the year 2015, 2016, and 2017 since the purpose of the literature review was to examine how *recently* published studies use the CI-based indices.

Chapter 3 Attitudes toward inequalities in income and health

"How selfish soever man may be supposed, there are evidently some principles in his nature, which interest him in the fortune of others, and render their happiness necessary to him, though he derives nothing from it except the pleasure of seeing it." ***-Adam Smith, The Theory of Moral Sentiments***

1.0 Introduction

Considerable attention has recently been paid to the levels and trends in inequalities in income and health (Alvaredo et al., 2017; Case and Deaton, 2015). Alongside an interest in the potential causes and effects of these inequalities (Deaton, 2013; Pickett and Wilkinson, 2015; Piketty, 2013; Stiglitz, 2015), their relationships to democracy and civic engagement (Bonica et al., 2013), and possible solutions to addressing them (e.g. Atkinson, 2014), there is a growing interest in understanding people's preferences and attitudes toward inequalities in income and health.

Understanding attitudes toward inequalities in income and health is central to welfare-based measurement approaches. Commonly used welfare-based measurement approaches such as the Atkinson index, the Gini coefficient, and the concentration-based indices, require assumptions regarding the extent to which people are averse to inequalities. These assumptions are reflected through an inequality aversion parameter which influences measured inequality. It is often assumed, however, that attitudes toward inequalities in income and health are the same. If inequality aversion preferences vary substantially across income and health, then models and measurement tools used for evaluating inequalities in income and health should reflect these domain-specific preferences. Recent studies of social preferences reveal heterogeneity across domains in other areas of economic attitudes, for example, risk aversion across domains including income and health (Einav et al., 2012; Hanoch et al., 2006; Vieider et al., 2015). Domain-specific risk aversion preferences have important implications for correctly calibrating economic models of insurance demand, savings, and labour supply (Einav et al., 2012; Fehr and Fischbacher, 2002). Moreover, there has been increased interest in explicitly incorporating inequality aversion preferences into health economic evaluations, such as cost-effectiveness analyses (Asaria et al., 2016; Cookson et al., 2009) so as to ensure that values held by the public, or their representatives, are adequately incorporated into decisions regarding the allocation of health care resources. It remains unclear whether preferences toward inequality vary across income and health, two important domains of wellbeing.

Understanding preferences toward inequalities in income and health is also relevant for devising welfare-enhancing policies and programs that are both likely to work and be supported by citizens. Policies and programs which reduce disparities in income and health constitute a large share of public expenditure in many countries through forms of collective insurance (e.g., universal access to health care), or via targeted policies and programs (e.g., earned income tax credits, minimum wage policies, and pensions) (Esping-Andersen and Myles, 2009). Among OECD countries, for instance, public social spending constitutes, on average, 21 percent of GDP (ranging from 15 to 30 percent), with pensions and health care accounting for two-thirds of this spending (OECD, 2016).

In addition to the policy oriented motivations for understanding peoples' attitudes toward inequality and examining the extent to which these preferences are domain-specific, findings from experiments and surveys indicate that people care about inequality *per se*. For instance, using functional magnetic resonance imaging (fMRI) to observe changes in brain activity, several experimental studies have shown that preferences for more equality activate the reward circuitry of the brain thereby affecting experienced reward (utility). These findings indicate that people have preferences for lower inequality because inequality has a negative impact on their experienced reward (Tricomi et al., 2010; Tricomi and Sullivan-Toole, 2015; Zaki and Mitchell, 2011). More recently, some (e.g., Starmans et al., 2017), have argued that that people care about fairness rather than inequality. By asking people to explain their reasoning, we can better understand whether fairness, inequality itself or other explanations motivate their preferences over inequality.

In this study, we investigate the attitudes of the public towards inequalities in income and health among a sample of the general public in Ontario, Canada. We use stated preference methods to empirically estimate inequality aversion (IA) towards univariate distributions of each of income and health, and the bi-variate distribution of income-related health inequality. Income-related health inequalities, in particular, play a prominent role in many disciplines, including economics, sociology, epidemiology, and geography. Systematic differences in health by income levels (or other proxies of socioeconomic status such as education or occupation) are of greater policy relevance than differences in health between individuals without considering their socio-economic status. We contribute to the literature by examining whether inequality aversion differs across income, health, and income-related health inequality. We use a structural model approach to estimate mean inequality aversion, in addition to estimating the median, the measure of central tendency which much of the existing literature has focused on. We also use descriptive qualitative methods to examine participants' explanations of their underlying reasoning and justifications for their choices.

Our findings indicate that attitudes toward inequality in the distributions of income and health differ in important ways. We estimate a mean IA of 3.27 for income inequality. Using the concept of equally distributed equivalent (Atkinson, 1970), this indicates that the public is willing to give up approximately 56% of mean income if the remainder is distributed equally. Inequality aversion toward income-related health inequality is consistent with the assumed value for the standard concentration index, a measure used in much of the health equity literature (Fleurbaey and Schokkaert, 2011). We estimate a mean IA of 1.66 toward the bivariate distribution of income-related health inequality; the standard concentration index assumes a value of 2.0. We find little variability by socio-demographic characteristics in our estimates of mean inequality aversion toward the distributions of income and of income-related health inequality. In contrast preferences towards inequality in health appear to be more heterogeneous than preferences toward income inequalities and income-related health inequalities. We find that approximately half of our participants are highly averse toward health inequality with a mean IA of 7.30

and approximately half display low levels of inequality aversion with a mean IA < 1.0. An IA of 7.3 indicates that society is willing to give up 1.7%[8] of mean health if the remainder is distributed equally, whereas an IA of less than 1 indicates that society is unwilling to give up any health for a more equal health distribution.

Our qualitative analysis of participants' comments provides further support of the main quantitative conclusion that there are differences in attitudes toward income inequality and health inequality. The qualitative analysis demonstrates that while some participants believe equality has intrinsic value, many base their preferences on beliefs about the causes or consequences of inequality. Some of these reasons were pragmatic (e.g., beliefs about the implications of inequality for society and the economy), whereas others provided ethical reasons (e.g., concern for the lowest quintile as a moral imperative).

2.0 Existing literature

In order to quantify the extent to which people are averse to inequalities, we follow the literature on estimating the value of the inequality aversion parameter within the context of a social welfare function. Two characteristics of this relatively small literature are of particular importance for our context. First, the literature on income features two basic approaches for assessing inequality aversion: the leaky bucket approach and the

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[8] It may seem counter-intuitive that a higher inequality aversion parameter results in a smaller proportion of the outcome that society is willing to redistribute, as observed for the univariate health distribution when compared to the univariate income distribution. This result is due to the narrower range (smaller variance) and lower mean for HALE compared to income. The full calculation is displayed in Appendix 3.11.

distribution approach. In contrast, only the distribution approach has been used in the health literature. Second, estimates of inequality aversion for the distribution of income differs across the two approaches, however, within each approach (leaky bucket versus distribution approach) the estimates of inequality aversion for income are consistent. In contrast, estimates of inequality aversion for the distribution of health differ markedly across studies and differ notably from inequality aversion for income.

The “leaky-bucket” approach (Okun, 1975) presents participants with scenarios involving a transfer of money from a rich person to a poor person. The transfer, however, involves a leak (e.g., in the form of administrative costs) such that the full amount given up by the rich person does not reach the poor person. Participants are asked to indicate the minimum amount that the poor must receive from the rich during the transfer (i.e., the maximum leakage that is acceptable). This tolerable leakage represents the tradeoff between efficiency (total amount of income available) and equality, with a higher tolerable leakage indicating greater inequality aversion.

The distribution approach presents participants with alternative hypothetical distributions of the outcome of concern (e.g., health) and asks participants to choose the distribution they prefer. One distribution has a higher mean level but greater dispersion (more unequal) —and the other has a lower mean level but less dispersion (more equal). The distributions are constructed such that given an assumed utility function and inequality aversion parameter, a person would be indifferent between the two distributions. The participant's choice reveals whether their inequality aversion parameter is greater (if the person chose the more equal distribution) or less (if they chose the more unequal distribution) than the assumed amount of inequality aversion.

2.1 Inequality aversion towards the distribution of income

Using the distribution approach Carlsson et al., (2005) and Johansson-Stenman et al., (2002) estimate median IA to be between 2.0 and 3.0 for the distribution of income. Using the leaky bucket approach, Amiel, Creedy, & Hurn (1999) and Cropper, Krupnick, and Raich (2016) obtain median IA estimates of 0.22 and 0.07 respectively for income. These are an order of magnitude smaller than estimates derived from the distribution approach.

Given the markedly different estimates for inequality aversion obtained using the leaky bucket and distribution approaches, Pirttila and Uusitalo (2010) estimate IA in income using both approaches. They find median IA below 0.5 for the leaky bucket approach, consistent with the leaky-bucket studies, and a median IA larger than 3 for the distribution approach, consistent with previous studies using this approach. Hence, the different estimates are likely due to the different measurement approaches. Pirttila and Uusitalo (2010) offer three potential reasons for the markedly different estimates using the two approaches. First, attitudes toward inequality may depend on how the scenarios are framed. The leaky-bucket experiment highlights the efficiency loss in a way that the distribution approach does not. Second, people may have different beliefs about factors that should contribute to income differentials. For instance, Pirttila and Uusitalo (2010) frame the distribution scenarios using wage bargaining. Income changes resulting from wage negotiations may be more desirable than changes resulting from income transfers. Third, the two approaches may be measuring a similar phenomenon, but on a different scale. Pirttila and Uusitalo (2010) write: "when an underlying latent preference for equality increases, one is first willing to support equal wage distribution; but the latent inequality preference must increase much more to trigger the person to support costly transfers" (page 67).

With the exception of Pirttila and Uusitalo (2010) and Cropper et al., (2016), which elicited preferences in a general population, other studies investigated IA for income using a student population. Moreover, these studies were conducted across different countries including Sweden, Finland, Israel, the USA and Australia (see Appendix 3.1 for a summary of the studies). Despite differences in study population (i.e., student versus general public) and geographic region, within each approach there is remarkable consistency in estimates of median IA for income.

2.2 Inequality aversion towards the distribution of health

Within studies using the social welfare function approach for eliciting IA preferences in health, the distribution approach dominates because, unlike income, health cannot be transferred between individuals (Dolan and Tsuchiya, 2011; Lindholm and Rosén, 1998). Using this approach, Lindholm and Rosén (1998) report median IA between 5 and 6. Similarly, both Andersson and Lyttkens (1999) and Edlin et al. (2012) report estimates between 4.6 to 6.7. In contrast, Dolan and Tsuchiya (2011) report a median IA estimate of 27.9. Using a slightly modified version of the questionnaire used by Dolan and Tsuchiya (2011), Robson, Asaria, Tsuchiya et al. (2016) report a median IA of 10.95. Cropper, Krupnick, and Raich (2016) report a median IA of 2.8.

The varied estimates of IA toward health may be due to differences in how the studies were framed and implemented. We discuss five key differences across the studies. First, studies have used different measures of health and attitudes toward inequality may depend on the particular health measure used. For instance, in Lindholm & Rosén (1998) the health measure is number of myocardial infarction cases prevented, while in Cropper, Krupnick, and Raich (2016) the health measure is risk for cancer. In Edlin, Tsuchiya, and Dolan (2012) the health measure is quality-adjusted life years and in Andersson and Lyttkens (1999), Dolan and Tsuchiya (2011), and Robson et al., (2016) the health measure is life expectancy. Second, some studies explicitly attribute the health differences to a particular disease and health *care* interventions. For example, in Lindholm and Rosén (1998), which framed the choice scenarios as the number of myocardial infarction cases prevented, the IA estimates may include attitudes towards fairness in the allocation of health care. Third, some studies framed the health differences as being related to socioeconomic status (e.g., Dolan and Tsuchiya, 2011; Lindholm and

Rosén, 1998; Robson et al., 2016), while others do not link differences in health to socioeconomic status (e.g,., Andersson and Lyttkens, 1999; Edlin et al., 2012) thereby estimating attitudes to 'pure' health inequality. Attitudes towards pure health inequalities may differ from attitudes toward socioeconomic-related health inequalities. Fourth, some studies present health differences in a negative frame, i.e., illness (e.g., Edlin et al., 2012; Lindholm and Rosén, 1998), whereas others present health differences in a positive frame using health gains (e.g., Dolan and Tsuchiya, 2011; Robson et al., 2016). The literature from prospect theory indicates that people treat gains and losses differently (Barberis, 2013) with people tending to be more averse to losses. Finally, some of the experiments were conducted face-to-face (e.g., Dolan and Tsuchiya, 2011; Edlin et al., 2012), whereas others were completed anonymously (e.g., Andersson and Lyttkens, 1999; Lindholm and Rosén, 1998). The face-to-face interviews may have been more likely to induce participants to make choices they believed were more socially desirable.

Given the multiple attributes which define each study, it is difficult to comment on systematic differences in IA estimates that may result from attributes of the study design. The single characteristic shared by all studies is the presentation of a series of choice scenarios for only the worst-off and the best-off members of society, rather than displaying a full distribution. By only considering the endpoints of a distribution differences may be exaggerated and give rise to more egalitarian stated preferences. This focus on the endpoints of a distribution may partially explain the higher estimates of aversion to health inequalities compared to income inequalities.

Our study builds on previous studies in several ways. First, like Cropper et al., (2016) we compare inequality aversion in income and health. However, in contrast to Cropper et al., (2016), we use the same methodology and frame the scenarios as similarly as possible across the domains, thereby allowing us to directly test for domain-specific preferences. Second, we use neutral language, whereas previous studies used terms like, pollution (e.g., in Cropper et al., 2016) or blue-collar/white collar (e.g., Lindholm and Rosén, 1998), social class 1 and social class V (e.g., Dolan and Tsuchiya, 2011) which may have independently affected responses. Third, to obtain an estimate that reflects only aversion towards health inequality rather than a mixture of both health and health-care related inequalities, we explicitly indicate that access to health care is the same for all groups in society. Fourth, we also obtain separate estimates for pure health inequality (unrelated to socio-economic status) and aversion to income-related health inequalities. Fifth, with the exception of Pirttila and Uusitalo (2010), previous studies ask participants to make a series of pairwise choices, and estimate inequality aversion using the point where participants switch their preference from a more equal choice to the less equal choice. To avoid biases resulting from order effects (where previous scenarios influences choices in subsequent scenarios), our design requires a response to only a single question. Finally, we introduce a structural approach to estimate the mean value of inequality aversion rather than focus on the median value. The structural model integrates the assumed social welfare function into the estimation process. In doing so, we are able to provide point estimates of mean IA, test for statistically significant differences in inequality aversion across the three domains, and determine whether and how inequality aversion varies by socio-demographic characteristics.

3.0 Empirical Approach: the social welfare function

By assuming a social welfare function at the outset, we adopt a formal approach to estimating inequality aversion, where the social welfare function allows us to quantify the extent to which people are averse to inequalities in income and health. We use the distribution approach and assume, as is commonly done in this literature, a constant relative risk aversion (CRRA) social welfare function to construct the univariate income and health distributions. As stated earlier, the distribution approach involves presenting participants with two distributions over which they would be indifferent if they had a particular IA value, and asks them to choose the distribution they prefer. The participant's response indicates whether their IA is greater or less than the assumed IA value.

The standard CRRA social welfare function is given by:

$$SWF = \sum_{i=1}^{N} \frac{y_i}{(1-\epsilon)}^{(1-\epsilon)} \; for\; \epsilon \neq 1, and\; \sum_{i=1}^{N} \ln{(y_i)} \; for\; \epsilon = 1,$$

where y_i represents the income/health of person i in a population of size N and ϵ is the inequality aversion parameter. The inequality aversion parameter (ϵ) can range from $\epsilon = 0$ where there is no concern for inequality and only average income/health in a population matters, resulting in a utilitarian social welfare function, to $\epsilon = \infty$ where all that matters is the income/health of the worst-off individual, resulting in a Rawlsian type SWF. As ϵ increases the weight given to individuals ranked lower in the income/health distribution increases relative to individuals ranked higher in the income/health distribution.

For the bivariate income-health distribution, we use the results from Bleichrodt and van Doorslaer (2006), who derive the Social Welfare Function underlying the Extended Concentration Index to construct the income-related health inequality distributions (Bleichrodt and van Doorslaer, 2006). In this case, individuals are now ranked by their income and average health is presented for each income level.

4.0 Experimental design and procedures

Our experimental survey comprised four sections: a) introduction with instructions; b) choice scenarios; c) social values orientation instrument; and d) socio-economic and demographic questions. Before administering the survey, we pilot-tested the survey in the McMaster Experimental Economics Laboratory using a university sample. The survey was subsequently refined based on feedback from the pilot tests. As an incentive to participate in the study participants were told that they would be entered into a draw for $250 (CAD) with guaranteed odds of at least 1 in 50.

4.1 Design of choice scenarios

The experiment consists of choice scenarios for three domains: income, health, and the bivariate distribution of income-related health inequality, each with the same five levels of assumed inequality aversion—1, 1.5, 2, 2.5, and 3[9]—resulting in 15 choice scenarios. Testing the same IA parameters across the three domains allows us to directly test for domain-specific preferences. Each choice scenario presents participants with two distributions of the outcome of interest—one distribution has a higher mean level but greater dispersion (more inequality); the other distribution has a lower mean level but less dispersion (more equal)—and the participant is asked which distribution they prefer. The distributions were constructed such that an individual with a given degree of inequality aversion, ϵ, would be indifferent between the two distributions. The choice regarding which distribution they prefer reveals whether inequality aversion is greater than or less than the IA value assumed when constructing the distributions. A preference for the lower-mean, more equal distribution would reveal that inequality aversion is greater than the assumed value; a preference for the higher-mean but more unequal distribution reveals the opposite[10]. In Table 3.1 we display the distributions accompanying each assumed IA value for the univariate income, health, and bivariate income-related health

[9] Constructing plausible health scenarios for inequality aversion parameters greater than 3 was also difficult since we present five income levels whereas previous studies presented only two and the distributions of HALE have a low mean.

[10] We did not include an 'indifferent' option, as Dolan and Tsuchiya (2011) report that participants found the 'indifferent' option confusing in their pilot tests. Previous studies that did include an 'indifferent' option found that a high proportion of participants would select this option. The NOAA guidelines on contingent valuation studies, led by Arrow, Solow and Portney (1993) recommends having only two options for participants to choose from.

inequality scenarios. Note that the reference distribution (Policy A) remained the same for all income choice scenarios while the more unequal distribution (Policy B) varied depending on the assumed IA value.

The reference income distribution reflects the actual distribution of household disposable income in Canada in 2010 (Parliament of Canada, 2013), while the reference health distribution reflects the Canadian distribution of health-adjusted life expectancy (Statistics Canada, 2011). The full set of distributions are available in Appendix 3.2.

We use a between-person design where each participant is randomly assigned a single choice scenario for each domain (income, health and the bivariate distribution of income-related health inequality). The experiment was designed assuming that each participant would be given a single question randomly allocated to them from the 15 possible choice scenarios. However, we randomly allocate three choice scenarios, one for each domain and test for bias resulting from order effects. In the presence of order effects, we were prepared to use responses from the first question only. The choice scenarios and the order in which they appear across the 15 versions of the experiment are available in Appendix 3.3.

4.1.1 Description of the choice scenarios

In our design, we sought participants' judgments about inequality for a hypothetical society they were not members of. Framing the choice scenarios in this way was done for two reasons. First, we sought participants' impartial judgments, and second, we wanted to keep participants' risk preferences separate from their preferences for equality[11]. That is, we wanted to capture participants' preferences for equality in a society *per se* rather than their beliefs about their own possible outcomes relative to the rest of the population.

In describing the scenarios we made simplifying assumptions to control for extraneous factors that could potentially affect participants' responses. For example, we indicated that citizens of the hypothetical country were similar in all respects except for the outcome of interest (i.e., income or health). The objective of our study was to estimate preferences toward inequality; preferences toward redistribution are distinct from preferences toward inequality (Alesina and Giuliano, 2011). We therefore presented the distribution resulting from each policy change, without information on the baseline, pre-policy distribution, to avoid eliciting preferences for redistribution. We described the scenarios using similar language across all three domains to keep the scenarios as similar as possible. This was done to reduce the influence of framing effects and cognitive biases as previous studies have demonstrated that even small differences in the presentation of the scenarios can alter choices (McFadden, 2001). We used annual income as a measure of income to allow us to compare our findings to the previous literature, since most

[11] It is important to conceptually distinguish between risk preferences and inequality aversion preferences. For this reason, the scenarios were not framed as choices from behind a veil of ignorance, a concept popularized by Harsanyi (1955) and Rawls (1971).

studies are focused on the distribution of income, rather than other forms of economic inequality, such as wealth or assets. Health-adjusted life-expectancy (HALE) was used as a measure of health. Although similar to life-expectancy, HALE allows for a larger range of values for developing scenarios that are both realistic and satisfy the CRRA social welfare function assumptions.

Below we present the description of the choice scenario for income:

> Imagine a hypothetical country in which citizens are identical in all ways except one: their incomes. The government must choose between implementing one of two policies. Both policies will have an impact on citizens' incomes. Indeed, the only impact of the policies is on the level and distribution of income within the population, though each policy affects the incomes of different groups differently. These impacts will not happen instantaneously, but will occur over the next 3-5 years. The table below presents information for each policy on the resulting yearly income for individuals in the country, after taking into account all taxes and government programs. (We present the same information in a graph below the table). In this country there are five levels of income, and the number of people with each income level is identical. In the table we label the income groups Inc1-Inc5, where Inc1 refers to the group with the lowest level of income and Inc5 refers to the group with highest level of income. Everyone within each income group has the same income, but incomes differ across the five groups. The government must choose between the two policies listed. We ask you which of the two policies you would prefer that the government implement.
>
> There is no right or wrong answer; we are interested in your personal judgment.

The two distributions were then presented in both graphical and tabular format since the results from our pilot testing indicated that participants found having both formats helpful in conveying information about the distributions. The full survey instrument is available in Appendix 3.4.

Participants were also provided with the opportunity to explain their choices. After the presentation of each choice scenario, participants were asked the following open-ended question "Why did you choose this policy?"

4.1.2 Social values orientation

To obtain an independent measure of participants' social attitudes, as part of the survey we elicited a measure of social values orientation (SVO) derived from social psychology (Messick and McClintock, 1968). This instrument has been validated and used in many disciplines including economics (e.g., Buckley et al., 2001; Offerman et al., 1996). The SVO exercise requires participants to make a series of 24 hypothetical money-sharing decisions between themselves and an unknown person with whom they are randomly matched (Liebrand and McClintock, 1988). As part of the actual experiment, no money was at stake and participants were not actually matched with an unknown person.[12] Based on their decisions, individuals were then classified into five categories; altruistic (maximize the pay-off to the other person), cooperative (maximize joint pay-offs), individualistic (maximize their own payoff), competitive (maximize their own pay off

[12] Mentzakis and Mestelman (2010) assess whether systematic differences arise between stated intentions and actual behavior, with real money, using the SVO exercise. The authors found no evidence for hypothetical bias.

relative to the other person), or aggressive (minimize the payoff to the other person). We use subjects' value orientations classification as a covariate when assessing heterogeneity in inequality aversion among participants.

4.2 Survey Administration

We administered the survey to a representative sample (drawn by a marketing research firm) of the community-dwelling population of Ontario, Canada, using a mixed-mode methodology (Gajic et al., 2012): individuals were invited to participate in the study via a letter sent by regular post, but then completed the survey online. Any adult member from the household was eligible to take part. Upon logging in, participants were randomly assigned to one of the 15 versions of the experiment.

5.0 Empirical Analysis

For each participant we have a single observation for each domain giving us three observations per participant. Each observation indicates whether the IA value of a participant is greater or less than the value assumed in the scenario to which they responded. Using these responses, we first tested for the presence of order effects by estimating separate probit models for each domain (income, health, income-related health inequality) and included a dummy variable where 1 indicates the domain in question was the first choice scenario presented to the participant and 0 otherwise. In these probit models, we also adjusted for participants' socio-demographic characteristics. Following the test of bias from order effects, we examined descriptive statistics of the distribution of IA values in the sample. As has been common in this literature the median IA value provides a point estimate for the population value. The median IA value is obtained by identifying the IA parameter value where 50 percent of the participants chose the more equal distribution (Policy A). This indicates that 50 percent have an IA value greater than the assumed value and 50 percent have a value less than the assumed IA value.

We then adopt a structural estimation approach to estimate mean inequality aversion.

5.1 Modeling inequality aversion within a random utility model

We adopt a random utility model (RUM) that corresponds to the assumed CRRA social welfare function. In doing so, the parameter estimates of IA are consistent with the design of the experiment: we structurally estimate the IA parameter. This approach has been previously used to structurally estimate the risk aversion parameter within the context of the CRRA social welfare function (see for e.g., Bombardini & Trebbi, 2012; De Roos & Sarafidis, 2010; Harrison, Lau, & Rutsrom, 2015; Harrison & Rutstro, 2008))[13]. To our knowledge, structural estimates of inequality aversion have not been previously reported.

---

[13]Harrison and Rutstro (2008) provide an overview of the methodology and examples of laboratory experiments employing this approach, as well as syntax for estimating the models using STATA. Syntax for estimating these models, as well as more complex variants, can also be found in Harrison, (2008).

The set-up of our experiment assumes participants have CRRA utility functions defined over the distributions of health and income in the hypothetical society. Each choice scenario in our experiment contains two distributions, A and B, and every distribution has 5 groups identified by j. Under the assumed CRRA social welfare function, the deterministic component of utility for participant i when presented with distribution A is

$$I_{iA} = \sum_{j=1}^{5} \frac{1}{(1-\epsilon)} y_{jA}^{(1-\epsilon)} \tag{1}$$

Similarly, the deterministic component of utility for participant i when presented with distribution B is

$$I_{iB} = \sum_{j=1}^{5} \frac{1}{(1-\epsilon)} y_{jB}^{(1-\epsilon)} \tag{2}$$

Allowing for an additive stochastic component of the utility function links latent preferences to participants' observed choices. We write these stochastic components as v_{iA} for distribution A and v_{iB} for distribution B. The unobserved heterogeneity in preferences captured by v_{iA} and v_{iB} may be known to the participant but unknown to the analyst or be a result of participants' mistakes. Therefore, random utility can be written as

$$\begin{aligned} U_{iA} &= I_{iA} = \sum_{j=1}^{5} \frac{1}{(1-\epsilon)} y_{jA}^{(1-\epsilon)} + v_{iA} \\ U_{iB} &= I_{iB} = \sum_{j=1}^{5} \frac{1}{(1-\epsilon)} y_{jB}^{(1-\epsilon)} + v_{iB} \end{aligned} \tag{3}$$

Maximizing utility, participant *i* will prefer distribution A if

$$
\begin{aligned}
P(A_i) &= P\,(U_{iA} > \ U_{iB}) \\
&= P(I_{iA} + v_{iA} > \ I_{iB} + v_{iB}) \\
&= P\big(v_{iA}\text{-}v_{iB}\big) > \text{-}(I_{iA}\text{-}I_{iB})\big)
\end{aligned}
\tag{4}
$$

Adopting the standard logistic distribution for v_{iA}-v_{iB} gives rise to a binary logit model. Under the constraint that $\epsilon \neq 1$ the likelihood can be maximized with respect to ϵ. In our case, the index function is non-linear therefore it is not necessary to normalize the distribution of v_{iA} or v_{iB}. The variance of v_{iA}-v_{iB} is $s^2\pi^2/3$ and we can estimate the scale factor, *s*. The corresponding probability of choosing distribution A is

$$
P(A_i) = \begin{cases} \Lambda\left(\dfrac{\frac{1}{(1-\epsilon)}\sum(y_{jA}^{(1-\epsilon)}\text{-}y_{jB}^{(1-\epsilon)})}{s}\right), & if\ \epsilon \neq 1 \\ \Lambda\left(\dfrac{\sum ln\frac{y_{jA}}{y_{jB}}}{s}\right), & if\ \epsilon = 1 \end{cases}
\tag{5}
$$

Where $\Lambda(.)$ is the standard logistic cumulative distribution function.

For the bivariate income-related health inequality scenarios, the same reasoning is followed using the utility function associated with the extended CI. The probability of choosing distribution A becomes

$$P(A_i) = \Lambda\left(\frac{\frac{\sum_{j=1}^{5}\left(r_j^{\epsilon}-(r_j-1)^{\epsilon}\right)(y_{iA}-y_{iB})}{5^{\epsilon}}}{s}\right) \qquad (6)$$

Where r_j is the ranking of the income groups from the hypothetical distribution in terms of socioeconomic status with r_j=1 referring to the richest quintile and r_j=5 to the poorest quintile.

For the above probability models (5) and (6), the parameters are estimated using maximum likelihood (ML) where the following function is maximized

$$\ln L = \sum_{i}^{N} lnP(A_i) \qquad (7)$$

Heterogeneity of mean IA values by participant's socio-demographic characteristics was examined through split sample estimation. The models were estimated using StataMP 15.

5.2 Qualitative assessment of participants' comments

Because the aim of the qualitative analysis of participants' comments about their choices was to identify common themes, we analyzed their comments using descriptive qualitative methods described in Sandelowski (2000) and Sandelowski (2010). The distinguishing characteristic of descriptive qualitative methods in comparison to other qualitative methods, such as grounded theory, is the level of interpretation. In descriptive qualitative methods, the analyst provides a literal interpretation of the data by staying closer to participants' actual words to form themes. Comments for each domain were sorted and coded separately. Within each domain, comments from participants who chose the more equal distributions were sorted and coded separately from those who chose the less equal distributions. The concepts that came up repeatedly (i.e., with the most comments attributed to them) were identified as the common themes. NVivo 10 was used for data management.

6.0 Results

6.1 Socio-demographic characteristics

Invitations to participate were mailed to 17,000 randomly selected individuals.[14] Of these individuals, 1,964 responded to at least one of the three choice scenarios for an overall response rate of 11.6 percent, which is typical for web-based surveys (Dillman, 2017; Dillman et al., 2014). Of the responders, 1,810 (92%) completed the survey in its entirety; we refer to this sample as the complete subsample. 154 (8%) participants partially completed the survey; we refer to this sample as the partial subsample (see table in Appendix 3.5). We further distinguish between the all-response (AR) data, which pools

[14] Approximately 50 letters were returned as undeliverable. This is likely an underestimate of undelivered letters because the postage stamp we used did not include returning undeliverable letters. As a result, the response rate is likely an underestimate.

the participants' responses to all three choice scenarios, and the first-response (FR) data which includes participants' responses to the first choice-scenario only.

Descriptive statistics comparing selected characteristics of our experimental sample to the Ontario population (based on the Canadian Community Health Survey) are presented in Table 3.2. In comparison to the Ontario population, our sample is older (mean of 59 years versus 44 years), contains a higher proportion of men (77% versus 48.8%), has a higher proportion of individuals that are married or in common-law relationships (84% versus 57%), a higher proportion of retirees (37.7% versus 16.6%), and a higher proportion of individuals reporting incomes greater than $100,000 (40.8% versus 26.1%). Other characteristics of our sample such as self-assessed health, education, and employment are comparable to the general population. The values-orientation scores classify 0.66% as aggressive, 3.2% as competitive, 24.2% as individualistic, 66.6% as cooperative, and 3.5% as altruistic. Table 3.3 displays participants' sociodemographic characteristics separately for each domain, demonstrating a balanced sample: a Kruskal-Wallis equality of population rank test indicates no statistically significant difference among covariates across the 15 versions of the survey. Note that participants are classified into the domains based on the domain of the first scenario to which they responded.

To correct for known differences in socio-demographic characteristics between our experimental sample and the Ontario population, we developed post-stratification weights for age and sex using the population estimates for the province of Ontario from the

Canadian Community Health survey[15]. A description of the post-stratification weights can be found in Appendix 3.6. The weighted and unweighted results provide qualitatively similar conclusions. We report both unweighted and weighted results.

6.2 Median inequality aversion

As shown in the table in Appendix 3.7, our tests confirmed the presence of order effects in the univariate distributions of income and health. Participants presented the income scenarios first were 11 percentage points more likely to choose the more equal income distribution than were those presented with the income scenario second or third ($p<0.001$); participants presented the health scenarios first were 10 percentage points less likely to choose the more equal health distribution than those presented with the health scenario second or third ($p<0.001$). In contrast, participants presented the bivariate choice scenarios first were neither more nor less likely to choose the more equal bi-variate distribution than those presented the bi-variate scenario second or third. Given the presence of order effects in the univariate income and health distributions, all subsequent analyses were conducted only on the first-response data.

The unweighted proportion of participants choosing the more equal distribution and the unweighted proportion choosing the less equal distribution for the assumed values of

[15] Re-weighted results using post-stratification weights for age, sex, and income are also available. These results are similar to the re-weighted results using post-stratification weights based on age and sex only. Using post-stratification weights for Canada did not result in substantial differences compared to using post-stratification weights for Ontario. These results are available upon request.

inequality aversion are tabulated in Table 3.4 for each of income, health, and income-related health inequality. The weighted results provide the same conclusions and can be found in the table in Appendix 3.8. For income, as the assumed value of inequality aversion increases the proportion of participants choosing the more equal distribution declines from 72.6% for an IA value of 1.0 to 65.4% for IA value of 3.0. Since more than 50 percent of participants chose the more equal distribution for the IA value of 3.0, the sample median IA for income is greater than 3.0. For health, as the assumed value of inequality aversion increases the proportion of participants choosing the more equal distribution declines from 50.8% for an IA value of 1.0 to 47.6% for an IA value of 3.0. The switch from more than 50 percent to less than 50 percent choosing the more equal distribution occurs between IA values of 1.0 and 1.5, indicating a sample median in this range. For the bivariate income-health distribution, as the assumed value of inequality aversion increases the proportion of participants choosing the more equal distribution declines from 80.3% for an IA value of 1.0 to 37.0% for an IA value of 3.0, with the sample median IA falling between 1.5 and 2.0. For all three domains we observe a slight increase in the proportion of participants choosing the more equal distribution as IA increases from 2.5 to 3.0. Although the differences in proportions are not statistically significant for the univariate distribution of health (p-value=0.883) or the bivariate distribution of income-related health inequality (p-value=0.509), though they are just barely significant at the 5% level for income (p-value=0.034).

The median IA value we obtain for income (IA > 3.0) is consistent with median IA values reported in previous studies using the distributional approach (Johansson-stenman et al., 2002; Pirttila and Uusitalo, 2010). The median IA value for health (between 1.0 and 1.5) is less than previously reported estimates, which range from 2.8 (Cropper et al., 2016) to 27.9 (Dolan and Tsuchiya, 2011). While IA for income-related health inequality has not been previously estimated, the median value we obtain is consistent with the assumed IA value for the standard concentration index of 2.0 (Wagstaff, 2002).

6.3 Mean inequality aversion

Table 3.5 displays the unweighted estimates of mean inequality aversion from the structural model overall (unadjusted for covariates) and by participants' sociodemographic characteristics using separate stratified models. The weighted estimates (table in Appendix 3.9) are similar to the unweighted estimates. In general, the inclusion of post-stratification weights resulted in smaller standard errors which increased the statistical significance of the estimates.

6.3.1 Mean inequality aversion from the structural model

The estimate of mean inequality aversion is 3.27 for income, is 1.17 for health, and is 1.66 for the bi-variate distribution of income-related health inequality. The estimated mean IA for income and the bivariate distribution of income-related health inequality are statistically significantly different from each other at the 5% level and statistically significantly different from zero at the 1% level. Mean IA for health is not statistically different from zero; nor is it statistically different from the IA estimates for either income or the bivariate distribution of income-related health inequality.

The descriptive statistics for choices regarding the health distributions indicated a highly bi-modal distribution of preferences in IA toward health inequalities. To investigate this further, we extended the structural model into a latent class (LC) setting (Cameron and Trivedi, 2005; Hurley et al., 2017). The LC model probabilistically classifies participants into classes, with each class representing a different preference pattern (Cameron and Trivedi, 2005). If the latent class analysis identifies more than one class, this provides additional support for heterogeneity in inequality aversion preferences towards the distribution of health. The latent class structural models are described in Appendix 3.10.

The latent class model identified two classes of approximately equal size (Table 3.6). About half, of the participants (49%) fall into Class 1 and exhibit high levels of aversion toward health inequalities (IA=7.3 and standard deviation = 0.091); 51% fall into Class 2 and exhibit low levels of aversion towards health inequalities (IA= 0.34 and standard deviation = 0.014). These findings are consistent with the empirical distribution displayed in Table 3.4.

A more intuitive interpretation of the IA estimates can be obtained using the concept of equally distributed equivalent: the mean level of income/health that, if distributed equally, would result in the same level of social welfare as the current distribution (Atkinson, 1970). For the reference income distribution presented to participants, which reflects the 2010 distribution of disposable income in Canada, an IA parameter of 3.27 would imply that society is willing to give up approximately 56% of mean income if the remaining 44% were equally distributed (an Atkinson index of 0.56, full calculation displayed in Appendix 3.11). On the other hand, an IA parameter of 7.3 toward the distribution of health implies that society is willing to give up 1.7% of mean health-adjusted life expectancy if the remaining 98% were distributed equally (an Atkinson index of 0.017, full calculation displayed in Appendix 3.11)[16]. An IA parameter of 0.34 indicates an unwillingness to reduce mean health to achieve a more equal health distribution.

Providing a similar redistributive interpretation for income-related health inequality is more complex since the equally distributed equivalent concept does not carry over to the bivariate social welfare function. Alternatively, for the bivariate case, in Figure 3.1 we display how members of society, ranked from richest to poorest, would be weighted if inequality aversion towards income-related health inequality changes from 2 (what is assumed for the standard CI) to 1.66. The change in IA from 2.0 to 1.66 when calculating

16 The univariate health distribution has a narrower range for HALE (smaller variance) when compared to the univariate income distribution, thereby resulting in a lower proportion to redistribute. The calculations for the univariate income and health distributions is displayed in Appendix 3.11.

the extended CI would decrease the estimate of income-related health inequality in Ontario for the same distribution from 0.0198 to 0.0154 - a 22% decline.[17]

6.4 Socio-economic and demographic correlates of heterogeneity in inequality aversion preferences

To assess the extent to which socio-demographic characteristics are correlated with participants' preferences for equality, below we report on a few notable correlates of IA from the structural model (Table 3.5). These estimates of mean IA are obtained by running separate stratified models by socio-demographic characteristic.

6.4.1 Socio-demographic characteristics & mean inequality aversion

Across all three domains, there is a consistent trend between IA values and three socio-demographic characteristics. Females are more averse to inequality than males. Participants reporting poor health (defined as having a self-assessed health as good, fair or poor) are more averse to inequality than those in good health (defined as having a self-assessed health as excellent or very good). And participants with a social values orientation as cooperative or altruistic are more averse to inequality than participants with a social values orientation as aggressive, competitive, or individualistic. However, within

[17] To illustrate the implications of changing the IA value on estimates of income-related health inequality using the extended CI, we used the health utilities index (HUI) as a measure of health since micro-level data on HALE for Ontario was not available. The HUI was adjusted for age, sex, and education.

each domain the differences in mean IA estimates for the aforementioned sociodemographic characteristics are not statistically significantly different from each other.

Differences across domains for two socio-demographic characteristics are worth noting, however, and these differences are most apparent for the univariate health distribution. Mean IA for the distribution of health for participants over the age of 60 is substantially higher (IA=6.4) than for those under the age of 60 (IA= 1). However, for income and the bivariate distribution of income and health, mean IA does not vary by age. Participants with high levels of education (post-secondary or university graduate) are more averse to health inequality (IA= 4.1) compared to participants with low education (post-secondary graduate, less than secondary and secondary school graduates), who exhibit very little inequality aversion (IA=1.0). In contrast, participants with high levels of education are less averse to income inequality (IA=2.95) and income-related health inequality (IA=1.61) compared to participants with low education (IA=3.32 towards income; IA=1.71 towards income-related health inequality). Again, the mean IA estimates for these sociodemographic characteristics are not statistically significantly different from each other.

In general, mean IA is approximately independent of socio-demographic characteristics for the univariate income distribution, with mean IA between 3.0 and 3.5. Previous studies have also reported a limited relationship between socio-demographic backgrounds and preferences toward inequality in the income distribution (Norton and Ariely, 2011; Piketty, 1999). Similarly, the variability in mean IA is small for the bivariate income-related health inequality distribution, ranging from a mean IA of 1.47 to 1.98. Much more variability is observed for inequality aversion for the health distribution with mean IA ranging from less than 1.0 to 6.4.

Three conclusions emerge from these results. First, differences in mean IA, both overall and in relation to socio-demographic characteristics, are apparent across domains. Preferences toward inequality appear to be domain specific, at least for income and health. Second, there is little variability in mean IA for income and income-related health inequality. Third, the distribution of IA in health is bi-modal, though the differences do no correlate strongly with socio-economic and demographic characteristics. This indicates that attitudes toward inequality may be based more on personal beliefs and perceptions that are shared by Canadians, rather than socio-demographic characteristics.

6.5 Participants reasoning for their choices

After each participant chose the distribution they preferred they were asked the following open-ended question: “Why did you choose this policy?” Although answering this question was not a requirement for completing the experiment a large proportion of the participants responded. Again, using only responses to the first scenario presented, 94% of the participants that completed the income scenarios provided a written comment

(628/671), 92% of the participants that completed the health scenarios provided a written comment (598/650), and 94% of the participants that completed the bivariate distribution of income-related health inequality scenarios provided a written comment (603/643).

These responses provide insights into the underlying arguments and justifications the public base their inequality preferences on. The commentary we received confirmed that participants understood the questions and that their choices were thoughtful and deliberate. Below we discuss the common themes in responses across domains. This is followed by a discussion on domain specific themes. Exemplary comments are provided throughout.

6.5.1 Common themes in participant responses across domains

Table 3.7 summarizes the common themes that emerged from participants who chose the more equal distribution in the scenario presented to them. Among those who chose the more equal distribution, three common themes emerged across all three domains; i) the concern for the lowest quintile, ii) the policy is fairer, and iii) the distribution is more equal (other terms used for this concept include the distribution is "more even", "has less disparity" or "has a smaller range"), see Table 1 in Appendix 3.12 for exemplary quotes for each domain:

> "I felt it was more important to help the poorer two income levels than the richer two levels even if it meant that the average income would go down." (Participant comment for choosing the more equal income distribution).

> “Policy A appears to help people because they are people and not because of income. I see that as being more fair.” (Participant comment for choosing the more equal health distribution).

> “Due to the fact that all income groups have the same amount of people, then, for the sake of equality, it would be best to even out the average life expectancy, otherwise, a fifth of the population would have a significantly lower life expectancy” (Participant comment for choosing the more equal bivariate distribution).

Some themes were common across two domains. Among participants who chose the more equal univariate income and univariate health distributions, a theme distinct to these domains was that the distribution resulted in better outcomes for the lower quintile groups which is good for society or the economy:

> "Societies are better off with less poverty. When lower income earners increase their income there is more economic activity than with lower incomes. The incidence of poverty is reduced and people live better, more healthy lives.” (Participant comment for choosing the more equal income distribution).

> "Policy A has a greater impact on the H1-H2 groups. If the health can be improved in these groups perhaps these individuals would cost our government less dollars and in fact these individuals could contribute to society" (Participant comment for choosing the more equal health distribution).

Among participants who chose the more equal univariate income and bivariate income-related health inequality distributions, a theme distinct to these domains was their concern for the lowest quintile groups since they are in greater need:

> "Policy A puts more money in the pockets of those who need it most, and less in the pockets of those who don't." (Participant comment for choosing the more equal income distribution).

> “This was actually a harder choice than I thought. Ultimately, it seemed unethical to choose a plan that would deprive the neediest sector of the population of adequate health coverage” (Participant comment for choosing the more equal bivariate distribution).

Among participants who chose the more equal univariate health and bivariate income-related health inequality distributions, a theme distinct to these domains was that the policy benefitted more people:

> "Because I think that Policy A would raise the level of health for more people even though some would not be raised to as high a level as possible." (Participant comment for choosing the more equal health distribution).

> "Policy A extends life expectancy for all income" (Participant comment for choosing the more equal bivariate distribution).

Table 3.8 summarizes the common themes from participants who chose the less equal distribution in the scenario presented to them. Among those who chose the less equal distributions, two common themes emerged across all three domains: the policy resulted in a higher average, and an opportunity to live longer/have a higher income (depending on the outcome), see Table 2 in Appendix 3.12 for exemplary quotes for each domain:

> "Greater opportunity for living healthy above average
> Policy B would give individuals a longer health-adjusted life expectancy while offering the same level of access to healthcare as in policy A." (Participant comment for choosing the less equal health distribution).

> "The average life-expectancy is higher, taking into account all income brackets, so it is fair. I believe in the utilitarian principle which suggests that the higher benefit given to the majority is the preferred option." (Participant comment for choosing the less equal bivariate distribution).

Again, some themes were common across two domains. A theme distinct to those who chose the less equal univariate income and bivariate income-related health inequality distributions was that the gains in the outcome (income, health-adjusted life expectancy) for the higher quintiles outweighed the losses to the lower quintiles:

> "Positive impact (in % terms) on higher income group is significantly greater than the negative impact on the lower income group." (Participant comment for choosing the less equal income distribution).

> "Although police A would benefit those in the lower income bracket, this benefit is not as significant as that when looking at the improvement in life expectancy for the higher income bracket that policy B appears to provide." (Participant comment for choosing the less equal bivariate distribution).

A theme distinct to the less equal univariate health and bivariate income-related health inequality distributions was that the policy benefitted more people:

> "I would prefer a higher level of health for all citizens, rather than a small group having a longer life. QUALITY OF LIFE is much more important to me than longevity. Death is inevitable" (Participant comment for choosing the less equal health distribution).

> "B benefited the greater number of people - I would have had a different answer if the groups were different, e.g., if group one had 60% of the population and the last group 1 per cent". (Participant comment for choosing the less equal bivariate distribution).

No themes were distinct to those who chose the less equal univariate income and univariate health distributions.

6.5.2 Domain specific themes

Some of the comments participants gave were more common within a specific *domain.* For the univariate income distributions several participants who chose the more equal distribution indicated that they did so because the alternative policy disproportionately benefitted the highest income groups:

> "Although under Policy B the overall average income of the country rises, the increasing average resides primarily with the one highest income group which is not equitable nor, I believe, beneficial to the country as a whole". (Participant comment for choosing the more equal income distribution).

Several participants that chose the less equal univariate income distribution indicated that they did so because it provided an opportunity for higher income which creates an incentive to work hard, and the higher overall income is good for the economy:

> "People need an incentive to improve their lives; if working harder doesn't benefit them, they will become complacent." (Participant comment for choosing the more unequal income distribution).

Two themes were unique to the bivariate income-related health inequality distributions: everyone, irrespective of income, should have access to good health, and that the alternative distribution benefits the rich at the expense of the poor:

> “I don't believe it is correct that the more money you make, the longer you live. In a democratic society, policy should not favour the rich, especially when the stakes are the highest possible--longer life.” (Participant comment for choosing the equal bivariate distribution).

Participants that were presented the univariate health scenarios appeared to struggle with understanding the variation in health outcomes, particularly since we stated that access to health care was the same in both scenarios. While some participants still attributed differences in health to differences in health care, this mistake was minimal. Instead, several participants made the assumption that differences in health outcomes are attributed to differences in consciousness and lifestyle factors:

> "I assume that the broader range of life expectancy is primarily based on lifestyle choices or economic status, both of which would not be duly influenced by higher or differently distributed health services."

In addition to the health scenarios being more difficult, some participants seem to hold strong beliefs about a longer HALE whereas others seem to hold strong beliefs about fairness and equality. For example, the opportunity to live longer as an end in itself was the dominant reason for choosing the less equal health distribution:

> "One assumes that a government's goal is to increase the health and longevity of its population. Policy B tends toward a longer life expectancy for groups H3-5. Advances in health care can improve H1 and H2 to "catch-up".

> "No one wants to die. To live that long in such good health is a bonus"

Moreover, several participants stated that additional years of health beyond a certain threshold isn't as meaningful and therefore it is better to increase health for the lower quintiles. This notion of a threshold did not arise for the income distribution or income-related health inequality:

> "I have older parents and recognize that beyond a certain age, life expectancy is not worth that much. So the choice of increasing the average as opposed to a more equal distribution was easy because the more equal distribution works most over"

Taken together the qualitative analysis of participant comments suggests that preferences towards inequality are varied and complex. Participants have various beliefs about the causes or consequences of inequality in addition to different ideas related to fairness and social justice. Importantly the comments indicate that differences do exist in preferences toward income inequality compared to health inequality, such as the concept of a health threshold where additional years are no longer meaningful.

There is remarkable consistency in the themes generated by comments in this study and comments provided by participants in a study investigating peoples' ethical views towards the distribution of income (Cowell et al., 2015). In their study, Cowell et al., (2015) ask people whether they agree or disagree to different scenarios each reflecting a different ethical principle. Of most relevance to our study are two scenarios, i) involved small benefits to several rich people at the cost of a loss on a disadvantaged member of society, and ii) involved giving absolute priority to the worst-off member regardless of the cost to the rest of society. The authors report similar groupings of participants' comments which include concern for the poor, utilitarian thinking, concern for equality, fairness, and efficiency. They also note that participants' comments included both ethical and economic reasons.

7.0 Robustness checks

We conducted two types of robustness checks. First, we estimate mean inequality aversion using an alternative reduced-form method which did not impose assumptions regarding the underlying functional form for preferences. Second, we further examined the relationship between socio-demographic characteristics and inequality aversion by estimating separate probit models for each domain. In these probit models, we simultaneously adjusted for socio-demographic characteristics, whereas previously we estimated separate stratified models for each characteristic unadjusted for other variables.

7.1 Modeling the inequality aversion parameter directly

The mean IA estimates derived from the structural model make strong functional form assumptions for the IA preferences based on the assumed social welfare function. As an alternative approach we estimate mean IA by directly modelling the inequality aversion distribution (adapted from the environmental economics literature, see Haab and McConnell, 2002). Directly modeling the inequality aversion parameter minimizes the need for *a priori* assumptions on the functional form of the parameter or the utility function in the econometric model. In doing so we are able to assess whether the CRRA social welfare function assumption is reasonable (if the estimated mean values from the two approaches are similar), or whether the estimates of mean IA using the structural approach impose too much structure on the parameter estimates (if the estimated mean values differ substantially).

We note, however, that because the CRRA social welfare function was used to create the distributions, the effect of the underlying CRRA cannot be escaped since its functional form is inherently represented through the constructed distributions for the varying IA parameters. Nevertheless, comparisons between the two approaches provide insight on the extent to which structure imposed within the random utility model potentially biases mean IA estimates.

For individual i we specify inequality aversion as a random parameter with a linear additive index function

$$IA_i = \beta + u_i \tag{8}$$

where β is a constant and $u_i \sim \Lambda(0, \frac{s^2\pi^2}{3})$ is an error term. Dichotomizing responses to a Yes/No format (i.e., Yes if Policy A was chosen and No if Policy B was chosen), an individual would respond Yes if their IA_i value was greater than the assumed inequality aversion parameter, ϵ_i, for the pair of distributions presented:

$$\begin{aligned} P(Yes_i) &= P(IA_i > \epsilon_i) \\ &= P(\beta + u_i > \epsilon_i) \\ &= P\left(\frac{\beta\text{-}\epsilon_i}{\sigma} > k_i\right) \\ &= \Lambda\left(\frac{\beta}{\sigma} \text{-} \frac{1}{\sigma}\epsilon_i\right) \end{aligned} \tag{9}$$

where $k_i \sim \Lambda\left(0, \frac{\pi^2}{3}\right)$ and $\Lambda\,(.)$ is the standard logistic distribution. For this logit model, $\frac{\beta}{\sigma}$ and $\frac{1}{\sigma}$ are estimable parameters, where, $\frac{\widehat{\beta}}{\sigma}$ will be an estimate of the model constant and $\frac{\widehat{1}}{\sigma}$ an estimate of the coefficient of ϵ_i.

Mean IA can be calculated by taking the expectation of eq. (8) with respect to u_i

$$E(IA_i|\beta) = \beta \qquad (10)$$

However, given that we do not observe β but only its scaled counterpart, a consistent estimate of mean IA following likelihood estimation is

$$E(IA_i|\beta) = \frac{\left(\frac{\widehat{\beta}}{\sigma}\right)}{\frac{\widehat{1}}{\sigma}} \qquad (11)$$

Table 3.9 displays the weighted and unweighted results of mean IA obtained from the direct approach. These estimates are slightly larger than the structural estimates of mean IA. For the direct approach, the unweighted mean IA is 4.42 95% CI (2.27, 6.57) for income, is 1.16 95% CI (0.00, 4.49) for health, and is 2.01 95% CI (1.84, 2.18) for the bivariate distribution of income-related health inequality. The weighted results are similar in magnitude to the unweighted results, but statistical significance is increased.

The differences in mean IA by sociodemographic characteristics are similar to the differences observed in the structural estimates for some characteristics (e.g., gender, self-reported health). However, the range of mean IA within domains is greater than for the structural models. Moreover, for some socio-demographic characteristics, such as low-education and poor health, the standard errors for the mean IA estimates are large suggesting that they are estimated less precisely, and therefore, these estimates should be interpreted with caution.

Although the direct approach (reduced-form estimation) to estimating mean IA does not explicitly test the CRRA assumptions, it is re-assuring that the overall estimates are broadly similar to estimates from the structural model and suggests that the CRRA assumptions may be reasonable.

7.2 Correlates of inequality aversion

We assessed the extent to which socio-demographic characteristics explain IA preferences, within each domain, by modelling the probability of choosing the more equal distribution as a function of socio-demographic characteristics. The dependent variable is binary, where 1 indicates choosing the more equal distribution and 0 indicates choosing the unequal distribution. We estimated separate probit models by domain, and adjusted for socio-demographic characteristics.

Table 3.10 displays average marginal effects for income in the left panel, health in the middle panel and bivariate in the right panel (marginal effects at the mean values of the dependent variables are available in the table in Appendix 3.13). In general, the socio-demographic variables are not significant and the magnitudes of the marginal effects are small. Hence, for each domain, socio-demographic characteristics do not in general explain much of the variation in inequality aversion preferences. The conclusions from these models, therefore, provide further indication that participants' socio-economic and demographic characteristics do not correlate strongly with their inequality aversion preferences.

There are, however, a few notable differences in the associations across domains. Differences are observed for the univariate health distribution and these differences are consistent with the structural estimates of mean IA. For example, participants with incomes greater than $75,000 are less likely to choose the more equal income distributions (9 percentage point difference) and bivariate distributions (10 percentage point difference), but income has no effect on choosing the more equal health distribution. Moreover, while university graduates are more likely to choose the more equal health distribution (12 percentage point difference), they are less likely to choose the more equal income distribution (5 percentage point difference).

8.0 Discussion

Attitudes towards inequality in the univariate distributions of income and health and the bivariate distribution of income-related health inequality have not been previously explored in a single study using similar methods. We find that inequality aversion preferences are domain-specific, and therefore, inequality aversion measured in one domain (e.g., income) cannot be assumed to be the same in other domains (e.g., health).

The strongly bi-modal distribution of inequality aversion towards the distribution of health has not been previously reported. The qualitative comments suggest that it was relatively more difficult for participants to make a choice for the univariate health inequality scenarios than it was for the univariate income inequality scenarios. Participants had a difficult time conceptualizing health differences, especially since we stated that access to health care is the same in both policies. This difficulty may be a result of the public's unfamiliarity with health differences, which contrasts with the income distribution since inequality in income has received far greater media attention. Moreover, our use of health-adjusted life expectancy (HALE) rather than life expectancy may have further complicated the health scenarios. Health-adjusted life expectancy is a more difficult concept to understand than life expectancy. Indeed, many participants seem to have treated the scenarios as differences in life expectancy. To the extent that participants understood the concept of HALE, there may have been an interaction between preferences toward health inequality and preferences toward the value of additional years in good health after a certain age (a type of time preference for health). Health naturally declines with age and this is not necessarily true for income. After a certain HALE threshold is reached, some people may value a more equal health distribution over a distribution that provides higher HALE for some. This is, to some extent, consistent with the fair innings argument (Olsen, 2013; Williams, 1997), which maintains that people should be given an equal chance at some reasonable length of life. Anyone failing to achieve this reasonable length of life has been cheated while anyone getting more than this is living on borrowed time (Williams, 1997). Moreover, this belief may become more salient as people get older. This may partly explain why IA for health for participants over the age of 60 is substantially higher than IA for health for participants 60 years of age and younger.

Our tests confirming the presence of order effects suggest that the order in which the domain is presented to participants affect their responses. Cowell et al., (2015) also report order effects in their study of ethical views towards the income distribution. Order effects have also been reported in the risk aversion literature (Harrison and Rutstro, 2008). It is now standard practise in the experimental literature to design studies in a way that allows the experimenter to control for bias from order-effects whenever the design of the experiment or survey requires participants to make a series of choices. Conclusions from previous studies eliciting inequality aversion preferences may, therefore, suffer from bias from order effects since almost all of the previous studies present participants with a series of choice scenarios and do not control or test for order-effects.

8.1 Limitations

A crucial assumption underlying our study—consistent with much of the literature—is that participants have preferences that can be reflected by the CRRA type social welfare function. Preferences, however, may not conform to this assumption. Specifying a social welfare function at the outset allows us to explicitly quantify the extent of inequality aversion. That the estimates of mean IA from directly estimating the IA distributions were comparable to the structural model estimates provides some reassurance of the study's main conclusion that preferences toward inequality are domain-specific.

Although we reweighted our experimental sample to match the Ontario population, the post-stratification weights are based on known differences between our experimental sample and the Ontario population. To the extent that there are important unobserved differences between our experimental sample and the Ontario population our results may not be generalizable to the Ontario population.

Hypothetical bias is a common criticism accompanying stated preference experiments because these experiments do not require real commitments and participants' choices do not have real consequences. The problem of hypothetical bias has been debated in the literature on stated preference experiments and the evidence of bias is mixed. Stated preference seems to be the only feasible design for eliciting preferences toward distributions of income and health and this approach follows the relevant literature. Moreover, the nature and direction of any such bias in our context is difficult to predict.

9.0 Conclusion

We find heterogeneity in attitudes toward inequality in the univariate and bivariate distributions of income and health, which are important domains of well-being. By incorporating attitudes toward inequality into the assessments of inequality, we can better understand the extent to which the current income or health distribution falls short of the idealized distributions (i.e., how much of the current income, health, income-related health inequality distribution is unfair?). Moreover, some may argue that in democratic societies, normative principles such as the extent to which inequalities in income and health matter should be in accordance with the values held by members of society. Engaging with citizens on key public policy issues, like inequalities in income and health, can also help with the development of interventions that are viable and more likely to receive public support. For example, many countries, including Canada, are currently experimenting with the idea of introducing some form of basic income, and debates surrounding the expansion of publicly funded health care to include prescription drugs and dental care continue to be a perennial health policy issue. Considering our findings on aversion toward income inequalities, it is perhaps not surprising that a universal basic income policy has been placed on the public-policy agenda. On the other hand, the contentious debates surrounding the provision and financing of health care might be partially explained by the public's diverse attitudes toward health inequalities.

In our experiment, participants' explanations for their choices reveal that inequality preferences are complex and heterogeneous across domains. Further research is therefore warranted on examining the motivations underlying these preferences – the what and why. By understanding why the public believes inequalities are a problem, whether they prefer to equalize opportunities, outcomes, access, or some other dimension of equality, and the kinds of inequalities considered problematic, we can design more appropriate policy levers for addressing inequalities in income and health.

Tables and Figures

Table 3.1 Income, health, and income-related health inequality distributions for varying degrees of inequality aversion

Panel A: Univariate income distributions						
	Inc1	Inc2	Inc3	Inc4	Inc5	Mean
Policy A: reference	\$14,600	\$32,700	\$49,700	\$73,500	\$135,500	\$61,200
Policy B: ϵ =1.0	\$12,200	\$30,700	\$49,700	\$75,500	\$168,500	\$67,320
Policy B: ϵ =1.5	\$13,900	\$32,000	\$49,700	\$74,300	\$166,700	\$67,320
Policy B: ϵ =2.0	\$14,200	\$32,300	\$49,700	\$73,900	\$166,500	\$67,320
Policy B: ϵ =2.5	\$14,400	\$32,700	\$49,700	\$73,500	\$166,300	\$67,320
Policy B: ϵ =3.0	\$14,550	\$32,700	\$49,700	\$73,500	\$166,100	\$67,310
Panel B: Univariate health distributions						
	H1	H2	H3	H4	H5	Mean
Policy A: reference	63.0	67.0	70.0	73.0	77.0	70.0
Policy B: ϵ =1.0	55.0	64.5	70.0	76.0	88.0	70.7
Policy B: ϵ =1.5	57.2	64.5	70.0	76.0	86.0	70.7
Policy B: ϵ =2.0	59.1	64.5	70.0	76.0	84.0	70.7
Policy B: ϵ =2.5	60.1	64.5	70.0	76.0	83.0	70.7
Policy B: ϵ =3.0	61.2	64.5	70.0	76.0	82.0	70.7
Panel C: Bivariate income-related health inequality distributions						
	Inc1	Inc2	Inc3	Inc4	Inc5	Mean
Income-Level	\$14,600	\$32,700	\$49,700	\$73,500	\$135,500	
Policy A: reference	64.0	67.0	70.0	73.0	76.0	70.0
Policy B: ϵ =1.0	54.0	60.0	70.0	80.0	86.0	70.0
Policy B: ϵ =1.5	56.8	67.0	70.0	80.0	86.0	72.0
Policy B: ϵ =2.0	60.6	67.0	70.0	80.0	86.0	72.7
Policy B: ϵ =2.5	62.2	67.0	70.0	80.0	86.0	73.0
Policy B: ϵ =3.0	63.0	67.0	70.0	80.0	86.0	73.2

Notes: The univariate health and bivariate income-related health inequality distributions present health-adjusted life expectancy in years for varying degrees of inequality.

Table 3.2 Characteristics of study sample (N=1810) and Ontario community-dwelling population

	Study Sample (%)	Ontario Population++ (%)		Study Sample (%)	Ontario Population++ (%)
Age (mean ± SD)	59 ± 12	44 ± 19	Education		
<18	0.11	8.28	Less than secondary school	3.48	5.27
18-24	0.77	11.18	Secondary school graduate	15.75	14.38
25-34	1.71	14.93	Post-secondary graduate	32.21	32.25
35-44	8.95	15.65	University graduate	46.52	43.67
45-54	22.21	16.52	Not stated	2.04	4.44
55-64	31.99	16.01	Income*		
65-74	24.64	10.46	No Income	0.39	0.35
75-80	5.52	3.79	< 20, 000	2.21	6.29
80+	3.09	3.18	20,000-49,000	11.82	26.5
Missing	0.99		50,000-74,000	17.46	20.62
Sex			75,000-100,000	16.02	20.16
Male	77.40	48.80	>100,000	40.77	26.09
Female	21.16	51.20	Self-assessed health status		
No Response	1.44		Excellent	18.51	21.23
Marital status			Very Good	43.04	37.93
Single (never married)	5.30	30.89	Good	28.01	28.27
Married or Common-law	84.03	57.08	Fair	8.45	8.88
Divorced or separated	5.75	7.25	Poor	1.44	3.56
Widowed	3.65	4.56	No stated don't know	10.55	0.13
Don't know, refusal, not stated	1.27	0.22	Social values orientation		
Employment status*			Aggressive	0.66	NA
Full-time	48.51	47.87	Competitive	3.20	NA
Part-Time	7.35	10.20	Individualistic	24.20	NA
Not employed	4.09	11.65	Cooperative	66.57	NA
Retired	37.73	16.57	Altruistic	3.48	NA

Don’t know, refusal, not stated	2.32	13.71	Other	1.88	NA
Dwelling ownership					
Own	92.38	72.50			
Rent	3.87	24.61			
Other	1.82				
Don’t know/refusal/ not stated	1.93	2.89			

Notes: ++Derived from the 2014 Canadian Community Health Survey.
*11% of experimental sample did not respond to the income question. CCHS data includes imputed income values. Around 30% of participants of CCHS did not respond to income question. Employment questions in CCHS only asked to those between the ages 16-75yrs. Those over the age of 75 were placed in the retired category (in addition to those between the ages of 16-75 stating they are retired)

Table 3.3 Characteristics of study sample by domain N = 1810

	Income		Health		Bivariate		Kruskal-Wallis test
	N	%	N	%	N	%	p-value
Age							0.43
Age ≤ 60	332	53.98	316	53.02	327	54.59	
Age > 60	339	46.02	280	46.98	272	45.41	
Sex							0.94
Females	127	20.65	137	22.99	119	19.87	
Males	477	77.56	453	76.01	471	78.63	
Self-assessed health							0.77
Poor health	228	37.25	233	39.36	225	37.75	
Good health	384	62.75	359	60.64	371	62.25	
Education							0.73
High Education	287	47.99	266	45.70	289	48.74	
Low Education	311	52.01	316	54.30	304	51.26	
Employment status							0.55
FT	306	49.76	270	45.30	302	50.42	
non-FT	284	50.24	320	54.70	288	49.58	
Income							0.91
Income < 75K	197	36.35	188	35.34	192	36.16	
Income ≥ 75K	345	63.65	344	64.66	339	63.84	
Social values orientation							0.68
Coop./Alt.	428	69.59	426	71.48	414	69.12	
Agg./Comp./Ind./Other	187	30.41	170	28.52	185	30.88	

Notes: Poor health defined as self-assessed health as good, fair or poor; good health defined as self-assessed health as very good, or excellent; high education defined as university, low education defined as post-secondary graduate, less than secondary and secondary school graduates. FT denotes full-time employment; non-FT denotes part-time, not-employed, or other employment; Coop.Alt. denotes cooperative or altruistic value orientation; Agg./Comp./Ind./Other denotes aggressive, competitive, individualistic or other social value orientation.

Table 3.4 Proportion of participants choosing each policy option across the assumed inequality aversion values, by domain

Domain	N	IA	More Equal Distribution (Policy A)* % (N)	95% CI	Less equal Distribution (Policy B) ‡ % (N)	95% CI
Income	124	1.0	72.58	[64, 80]	27.42	[20, 36]
	135	1.5	68.15	[60, 76]	31.85	[24, 40]
	136	2.0	67.65	[59, 75]	32.35	[25, 41]
	140	2.5	52.86	[44, 61]	47.14	[39, 56]
	136	3.0	65.44	[57, 73]	34.56	[27, 43]
Health	122	1.0	50.82	[42, 60]	49.18	[40, 58]
	130	1.5	49.23	[41, 58]	50.77	[42, 59]
	139	2.0	48.20	[40, 57]	51.80	[43, 60]
	135	2.5	46.67	[38, 55]	53.33	[45, 62]
	124	3.0	47.58	[39, 56]	52.42	[44, 61]
Bivariate	132	1.0	80.30	[73, 86]	19.70	[14, 27]
	124	1.5	56.45	[47, 65]	43.55	[35,53]
	130	2.0	43.85	[35, 53]	56.15	[47, 65]
	130	2.5	33.08	[25, 42]	66.92	[58, 75]
	127	3.0	37.01	[29, 46]	62.99	[54, 71]

Notes: *The more equal distribution has a lower mean but also lower variance. ‡ The less equal distribution has a higher mean but also higher variance. Proportions are unweighted.

Table 3.5 Structural estimates of the mean inequality aversion estimates for income, health, and the bivariate distribution of income-related health inequality

	Income distribution		Health distribution		Bivariate distribution	
	ϵ	$\ln(\sigma)$	ϵ	$\ln(\sigma)$	ϵ	$\ln(\sigma)$
Overall	3.27***	-23.43***	1.17	-2.04	1.66***	0.81***
	(0.81)	(7.72)	(0.75)	(3.82)	(0.08)	(0.13)
Age ≤ 60 yrs.	3.16***	-22.97**	1.00**	-2.38	1.86***	0.76***
	(0.95)	(9.00)	(0.43)	(2.21)	(0.14)	(0.19)
Age > 60 yrs.	3.30**	-23.32*	6.41	-22.52	1.54***	0.70***
	(1.36)	(12.91)	(17.40)	(69.65)	(0.08)	(0.16)
Females	3.33**	-24.69**	1.63***	-5.00**	1.73***	0.86***
	(1.30)	(12.35)	(0.54)	(2.30)	(0.20)	(0.31)
Males	3.23***	-23.03**	1.24	-2.21	1.64***	0.70***
	(0.96)	(9.14)	(0.95)	(4.76)	(0.08)	(0.13)
Poor health	3.36***	-24.51**	1.89*	-5.30	1.72***	0.57***
	(1.15)	(10.93)	(1.05)	(3.99)	(0.11)	(0.18)
Good health	3.14***	-22.21**	1.05	-1.78	1.63***	0.81***
	(1.10)	(10.45)	(0.82)	(4.21)	(0.10)	(0.16)
High Education	2.95**	-20.57*	4.15	-14.19	1.61***	0.54***
	(1.22)	(11.60)	(6.59)	(25.48)	(0.08)	(0.15)
Low Education	3.32***	-23.94**	0.58	-0.10	1.71***	0.88***
	(1.00)	(9.53)	(0.97)	(4.89)	(0.12)	(0.20)
FT employed	3.26**	-22.90	1.72***	-5.30***	1.51***	0.69***
	(1.61)	(15.36)	(0.43)	(1.75)	(0.08)	(0.16)
non-FT	3.25***	-23.90***	0.00	4.12**	1.88***	0.72***
	(0.87)	(8.32)	(0.03)	(1.96)	(0.13)	(0.18)
Income < 75K	3.51***	-26.59***	0.95	-1.42	1.98***	0.67***
	(1.00)	(9.56)	(1.24)	(6.36)	(0.18)	(0.24)
Income ≥ 75K	3.00**	-20.68*	2.28	-6.66	1.47***	0.76***
	(1.18)	(11.19)	(1.58)	(5.53)	(0.08)	(0.16)

Coop./Alt.	3.19***	-22.90***	2.29**	-7.09**	1.71***	0.64***
	(0.80)	(7.59)	(1.00)	(3.50)	(0.09)	(0.14)
Agg./Comp./Ind./Other	3.52	-25.14	0.00	2.35***	1.53***	1.15***
	(2.66)	(25.30)	(0.00)	(0.40)	(0.15)	(0.27)

Notes: * p<0.05, ** p<0.01, *** p<0.001. Standard errors in parenthesis. σ represents the standard deviation of the inequality aversion parameter. With the exception of 'Overall', split-sample models were estimated. Poor health defined as self-assessed health as good, fair or poor; good health defined as self-assessed health as very good, or excellent; high education defined as university, low education defined as post-secondary graduate, less than secondary and secondary school graduates. FT denotes full-time employment; non-FT denotes part-time, not-employed, or other employment; Coop.Alt. denotes cooperative or altruistic value orientation; Agg./Comp./Ind./Other denotes aggressive, competitive, individualistic or other social value orientation.

Table 3.6 Mean IA estimates for the health distribution from latent class structural estimation

	ϵ	$\ln(\sigma)$	Class share
Class 1	7.30**	-2.40	0.49
	(3.51)	(0.94)	
Class 2	0.34	-4.28	0.51
	(0.42)	(0.44)	

Notes: standard errors are in parenthesis and are estimated using 250 bootstrap replications σ represents the standard deviation of the inequality aversion parameter.

Table 3.7 Common themes for choosing the more equal distribution

Income	Health	Bivariate
Concern for lowest quintile	Concern for lowest quintile	Concern for lowest quintile
Better outcomes for the lower quintile groups and this is good for society/economy	Better outcomes for the lower quintile groups and this is good for the economy/society	Concern for the lowest quintile groups because they are in greater need
Concern for the lowest quintile groups because they are in greater need	Benefits more of society	Everyone, irrespective of income, should have access to good health
More fair	More fair	More fair
Alternative policy disproportionately benefits the highest income group only	More equal/even/better distribution/ less discrepancy	More equitable (other terms for this concept include more even, smaller range, less disparity)
More equitable (other terms for this concept include more even, smaller range, less disparity)	More equal and this is good for the economy/society	Alternative benefits rich at the expense of the poor
		Benefits more people

Table 3.8 Common themes for choosing the more unequal distribution

Income	Health	Bivariate
Higher average	Higher average	Higher average
Higher average and this is good for society/economy	Opportunity to live longer	Opportunity to live longer
Opportunity for higher income creates an incentive to work hard	Benefits the healthier and they should have the opportunity to live longer	Higher income earners will live longer and this is good for the economy/society
Opportunity for higher income	Benefits more people	Gains in life expectancy outweigh losses to lower income
Higher overall income is good for the economy	A more realistic health distribution	Benefits more people
Benefits to higher quintile outweigh loss to lower quintile		

Table 3.9 Mean inequality aversion estimates for income, health, and the bivariate distribution of income-related health inequality from the direct approach

	Income		Health		Bivariate	
	ϵ	ϵ (weighted)	ϵ	ϵ (weighted)	ϵ	ϵ (weighted)
Overall	4.42***	4.48***	1.16	1.61***	2.01***	1.95***
	(1.10)	(0.74)	(1.70)	(0.60)	(0.09)	(0.07)
Age ≤ 60 yrs.	3.20***	3.54***	0.81	1.09	2.22***	2.36***
	(0.38)	(0.45)	(1.16)	(0.79)	(0.13)	(0.13)
Age > 60 yrs.	8.78	6.33**	3.86	2.34**	1.84***	1.77***
	(13.25)	(3.02)	(4.85)	(0.97)	(0.11)	(0.08)
Females	4.10***	4.68***	1.87***	1.64***	2.08***	2.19***
	(1.37)	(0.98)	(0.57)	(0.33)	(0.25)	(0.14)
Males	3.84***	4.04***	1.40	1.60	1.98***	1.82***
	(0.80)	(0.96)	(1.57)	(1.68)	(0.09)	(0.08)
Poor health	6.50	10.98	2.12***	1.99***	2.06***	1.92***
	(4.54)	(13.06)	(0.80)	(0.57)	(0.12)	(0.08)
Good health	3.37***	3.69***	1.01	1.23	1.97***	1.95***
	(0.59)	(0.47)	(1.85)	(1.05)	(0.11)	(0.11)
High Education	2.82***	2.91***	2.73***	2.61***	1.92***	1.88***
	(0.29)	(0.25)	(0.75)	(0.50)	(0.10)	(0.07)
Low Education	11.22	19.04	-4.00	7.87	2.07***	1.98***
	(17.89)	(36.98)	(26.03)	(19.73)	(0.14)	(0.14)
FT employed	6.58	15.71	1.99***	1.93***	1.80***	1.67***
	(7.44)	(35.33)	(0.42)	(0.22)	(0.12)	(0.08)
non-FT	3.42***	3.39***	5.60	2.22***	2.23***	2.41***
	(0.43)	(0.30)	(34.68)	(0.56)	(0.12)	(0.12)
Income < 75K	5.63**	5.68***	-1.40	6.18	2.28***	2.13***
	(2.80)	(1.80)	(20.56)	(12.13)	(0.13)	(0.11)
Income ≥ 75K	3.03***	3.57***	2.31***	2.67***	1.76***	1.73***
	(0.43)	(0.53)	(0.62)	(0.65)	(0.13)	(0.10)

Coop./Alt.	3.60***	4.14***	2.34***	2.47***	2.06***	2.01***
	(0.54)	(0.59)	(0.44)	(0.31)	(0.10)	(0.08)
Agg./Comp./Ind./Other	-2.02	17.39	3.21***	3.36***	1.88***	1.79***
	(7.43)	(82.85)	(0.90)	(0.58)	(0.19)	(0.13)

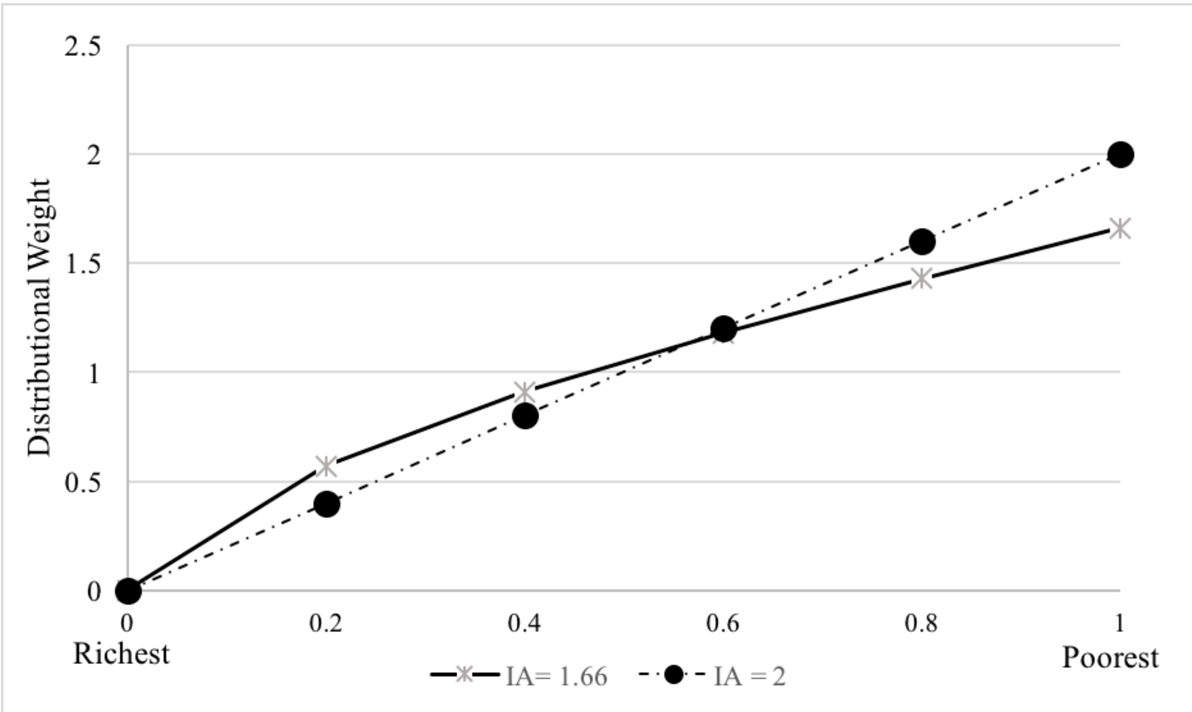
Notes: * p<0.05, ** p<0.01, *** p<0.001. Standard errors in parenthesis. With the exception of 'Overall', split sample models were estimated. Poor health defined as self-assessed health as good, fair or poor; good health defined as self-assessed health as very good, or excellent; high education defined as university, low education defined as post-secondary graduate, less than secondary and secondary school graduates. FT denotes full-time employment; non-FT denotes part-time, not-employed, or other employment; Coop.Alt. denotes cooperative or altruistic value orientation; Agg./Comp./Ind./Other denotes aggressive, competitive, individualistic or other social value orientation.

Table 3.10 Predicted probability of choosing the more equal distribution for each of income, health, and bivariate scenarios

	Income		Health		Bivariate	
	Coefficient	Coefficient weighted	Coefficient	Coefficient weighted	Coefficient	Coefficient weighted
ε =1.0	reference		reference		reference	
ε =1.5	-0.026	0.028	0.041	0.110*	-0.235***	-0.253***
	(0.066)	(0.046)	(0.071)	(0.049)	(0.063)	(0.043)
ε =2.0	-0.06	-0.061	0.03	0.069	-0.361***	-0.352***
	(0.067)	(0.045)	(0.068)	(0.046)	(0.059)	(0.039)
ε =2.5	-0.204**	-0.156***	-0.04	-0.045	-0.487***	-0.494***
	(0.064)	(0.044)	(0.071)	(0.051)	(0.055)	(0.037)
ε =3.0	-0.125	-0.06	-0.029	0.056	-0.440***	-0.387***
	(0.066)	(0.045)	(0.071)	(0.049)	(0.059)	(0.04)
Age > 60 yrs.	0.006	-0.01	-0.102	-0.062	0.049	0.055
	(0.049)	(0.035)	(0.054)	(0.037)	(0.054)	(0.037)
Female	0.125*	0.138***	-0.022	-0.032	0.046	0.070*
	(0.053)	(0.027)	(0.055)	(0.032)	(0.052)	(0.028)
Poor health	0.059	0.056	0.07	0.013	-0.002	0.01
	(0.044)	(0.032)	(0.046)	(0.032)	(0.043)	(0.029)
High education	-0.045	-0.108***	0.116*	0.082*	0.007	0.01
	(0.041)	(0.027)	(0.046)	(0.032)	(0.042)	(0.029)
FT employed	-0.039	-0.042	-0.029	-0.037	-0.048	-0.109**
	(0.048)	(0.032)	(0.055)	(0.037)	(0.054)	(0.036)
Income ≥ 75K	-0.089	-0.075*	0.002	0.008	-0.096*	-0.059
	(0.047)	(0.031)	(0.051)	(0.034)	(0.047)	(0.032)
Coop./Alt.	0.049	0.060*	0.094	0.185***	0.04	0.05
	(0.045)	(0.03)	(0.049)	(0.033)	(0.045)	(0.031)

Notes: * p<0.05, ** p<0.01, *** p<0.001. Standard errors in parenthesis. Poor health defined as self-assessed health as good, fair or poor, reference category is good health defined as self-assessed health as very good, or excellent; high education defined as university graduate, reference category is low education defined as post-secondary graduate, less than secondary and secondary school graduates; FT employed denotes full-time employment, reference category is non-FT which includes part-time, not-employed, or other employment; Coop.Alt. denotes cooperative or altruistic value orientation, reference category is Agg./Comp./Ind./Other denotes aggressive, competitive, individualistic or other social value orientation.

Figure 3.1 Distributional weights in the socioeconomic status distribution for an inequality aversion (IA) value of 1.66 and 2.0.



Note: The absolute value of the weights is displayed.

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Appendices

Appendix 3.1

Table 1 Summary of studies

Domain	Study	Preference elicitation method	Study population	Inequality aversion estimate
Income	Amiel, Creedy, & Hurn, (1999)	Leaky Bucket	N=72 (Australia, 41; Israel, 31)	Median 0.22
	Pirttila & Uusitalo, (2010)	Leaky Bucket, Distribution	N=3000 general public (Finland)	Median >3 (distributional)
	Cropper, Krupnick, & Raich, (2016)	Leaky Bucket	N=913 general public (United States)	Median = 0.07
	Johansson-Stenman, Carlsson, & Daruvala, (2002)	Distribution	N=374 students (Sweden)	Median 2-3
	Carlsson, Daruvala, & Johansson-Stenman, (2005)	Distribution	N=324 students (Sweden)	Median 1-2
Health	Lindholm & Rosén, (1998)	Distribution	N= 449 Health care politicians (Sweden)	Median 5-6
	Andersson & Lyttkens, (1999)	Distribution	N=225 students (Sweden)	4.7 6.7
	Dolan & Tsuchiya, (2011)	Distribution	N=467 (United Kingdom)	Median 27.9
	Edlin, Tsuchiya, & Dolan, (2012)	Distribution	N=559 general public (England and Wales)	4.76 (4.48-5.04) 6.63 (5.98-7.28)
	Robson, Asaria, Cookson, Tsuchiya, & Ali, (2016)	Distribution	N= 264 general public (England)	Median 10.95
	Cropper et al., (2016)	Distribution	N=913 general public (United States)	Median 2.8

Appendix 3.2 Construction of the univariate and bivariate distributions

We construct three types of distributions; univariate income, univariate health, and bivariate income and health distributions. The distributions were constructed such that, under a specified social welfare function (SWF), a person with an assumed value of inequality aversion (IA) would be indifferent between the distributions. The survey presents participants with two distributions, where both distribution have the same amount of total social welfare, and asks participants which distribution they prefer. If a participant chooses the higher mean more unequal distribution, this implies that their IA is less than the presumed IA value (the IA parameter assumed when constructing the scenario). If the participant choses the lower mean but more equal distribution, this implies that their IA parameter is greater than the value assumed.

Univariate Income distribution

We assume the following:

- Five levels of income in the society, resulting in five income quintiles
- Equal numbers of people in each income level
- Standard Atkinson social welfare function (SWF)

The standard Atkinson Social Welfare Function:

$$SWF = \sum_i \frac{x_i}{(1-\nu)}^{(1-\nu)} \; for\ \nu \neq 1, and \ln(x_i)\ for\ \nu = 1$$

Let the five quintiles be denoted by X_L, X_1, X_2, X_3, X_4, X_H. This is our reference distribution. We then construct a second distribution for which, based on the SWF, as person would be indifferent. To construct the alternative distribution, we change the income levels of the highest and lowest income quintiles so as to leave the value of the SWF unchanged (total social welfare in the two societies need to remain constant). We construct a new distribution with a higher mean but greater inequality such that a person would be indifferent.

- We increase the mean income in the alternative distribution by 10% compared to the mean of the original distribution
- We change income of only the highest (X_H) and lowest quintiles (X_L)

Taking the derivative of the SWF with respect to the income levels we get:

$$\frac{\partial SWF}{\partial x_i} = x_i^{-\nu}$$

Let α be the rate of leakage during a transfer. We want to find the α such that, for a given ν and transfer, T, from X_H to X_L, SWF is unchanged:

$Tx_H^{-v} = (1\text{-}\alpha)\, Tx_L^{-v}$

Solving this for α, we get:

$$\alpha = 1 - \left(\frac{X_L}{X_H}\right)^v$$

If we add a given amount of income to the high-income group, and $(1 - \alpha)$ to the low income group, the mean will increase but social welfare will not change. We need to determine how large the increase in income for the highest-income quintile, which, together with the associated change in income to the lowest-quintile group, will achieve the desired increase (of 10%) in average income in the alternative society. Let δ be the desired percentage increase in mean income in society, and let D_H be the increase in income in the highest-quintile group. Then the following condition must hold:

$$\bar{X} + \delta \bar{X}_{pre} = \frac{x_L\text{-}(1-\alpha)D_H + A + (x_H + D_H)}{5}$$

Where:

A = sum of x_2, x_3, x_4
$\bar{X}_{pre}$ = pre-change mean income
δ = percentage change in mean income pre and post

Solving for D_H we get:

$$D_H = \frac{5\delta\bar{x}_{pre}}{\alpha}$$

Note that a person's degree of inequality aversion enters through α.

Another way to think about this is as follows. Again, let D_H be the increase for the highest quintile, and D_L be the decrease for the lowest quintile. We know that the following must hold true for there to be no change in social welfare:

$$D_L * x_L^{-\nu} - D_H * x_H^{-\nu} = 0$$

Solving for $D_L = D_H \left(\frac{x_L}{x_H}\right)^{\nu}$

For large D_H this is an approximation. But it provides a starting point and we can make minor changes to obtain the exact change required. We therefore proceed as follows:

1. Use the formula for α to get an estimate of the leakage rate
2. Use the formula for D_H to get a starting value for D_H
3. Use the formula for D_L to get the corresponding value for D_L

4. Then iterate varying two parameters: an adjustment factor for D_L that adjusts the rate of leakage and D_H to get the combination of D_H and D_L that increase the mean as desired and leaves social welfare unchanged

We end up with the following income distributions:

	Inc1	Inc2	Inc3	Inc4	Inc5	Mean
Policy A: reference	$14,600	$32,700	$49,700	$73,500	$135,500	$61,200
Policy B: v =1.0	$12,200	$30,700	$49,700	$75,500	$168,500	$67,320
Policy B: v =1.5	$13,900	$32,000	$49,700	$74,300	$166,700	$67,320
Policy B: v =2.0	$14,200	$32,300	$49,700	$73,900	$166,500	$67,320
Policy B: v =2.5	$14,400	$32,700	$49,700	$73,500	$166,300	$67,320
Policy B: v =3.0	$14,550	$32,700	$49,700	$73,500	$166,100	$67,310

<u>Univariate Health Distributions</u>

We used the same basic approach for the univariate health distribution, with a few minor modifications that reflect differences in the distributions

- We use health adjusted life expectancy (HALE) as a measure of health
- Given the relatively low level of inequality (compared, for instance, to the income data), changing the mean by 10 percent required implausible changes in HALE. We did two things to deal with this:
  a) Increased mean HALE by only 1%, and b) even with this we push the boundaries of plausibility for the highest-health quintile

The resulting health distributions are as follows:

	H1	H2	H3	H4	H5	Mean
Policy A: reference	63.0	67.0	70.0	73.0	77.0	70.0
Policy B: v =1.0	55.0	64.5	70.0	76.0	88.0	70.7
Policy B: v =1.5	57.2	64.5	70.0	76.0	86.0	70.7
Policy B: v =2.0	59.1	64.5	70.0	76.0	84.0	70.7
Policy B: v =2.5	60.1	64.5	70.0	76.0	83.0	70.7
Policy B: v =3.0	61.2	64.5	70.0	76.0	82.0	70.7

Bivariate income and health distributions

The biggest challenge to implementing our approach is using the social welfare function approach for the bivariate distribution. We can use the results in Bleichrodt and van Doorslaer (2006), who derive the social welfare function underlying the extended CI (ECI), which allows for varying degrees of inequality aversion. They demonstrate that under common assumptions about preferences, plus a few more specific to the Gini/CI, the social welfare function underlying the ECI is as follows:

$$SWF_{ECI} = F(h) = \sum_{i=1}^{n} a_i h_i = \frac{\sum_{i=1}^{n}(i^{v}\text{-}(i\text{-}1)^{v})\tilde{h}_i}{n^{v}}$$

Where the ranking is in terms of socioeconomic status. Note, for Bleichrodt and van Doorslaer (2006) rank =1 refers to the richest person, rank =5 the poorest, which is the opposite of usual conventions. $F(h)$ is simply an expression for Wagstaff's achievement index, $A(v)$. Further, this expression is equal to $\mu(h)(1 - C(v))$. Hence we get:

$$SWF_{ECI} = F(h) = A(v) = \mu(h)(1 - C(v))$$

Where $C(v)$ is the extended concentration index (ECI), and $A(v)$ is the abbreviated social welfare function underlying the ECI.

For a population of size 5 (corresponding to quintiles), it is easy to calculate the weights associated with different values v. Then we simply need to ensure that, for a given value of v:

$\Delta h_1 {*}(a_1) + \Delta h_1 {*}(a_2) + \Delta h_3 {*}(a_3) + \Delta h_4 {*}(a_4) + \Delta h_5 {*}(a_5) = 0$

Where the a_i are the weights. Here are the specific weights of quintile-v combinations:

	h_1	h_3	h_4	h_4	h_5
ν=1	1.00	1.00	1.00	1.00	1.00
ν=1.5	1.00	1.83	2.37	2.80	3.18
ν=2	1.00	3.00	5.00	7.00	9.00
ν=2.5	1.00	4.66	9.93	16.41	23.90
ν=3.0	1.00	7.00	19.00	37.00	61.00

Given these weights, it is easy to modify health distributions across income quintiles to maintain constant social welfare under different assumptions regarding v. For instance, if $v = 2.0$, and we consider only changes between h_1 and h_5, if we add 1 unit of health to h_5, we would need to reduce the health of h_1 by 9 units to maintain indifference with the original distribution; if $v = 1.5$, we would need to reduce h_1 by only 3.18 units (because we are less inequality averse than when $v = 2$).

Applying this approach, and using the income and health distributions from above, we get the following distributions:

	Inc1	Inc2	Inc3	Inc4	Inc5	Mean
Income levels	\$14,600	\$32,700	\$49,700	\$73,500	\$135,500	
Policy A: reference	64.0	67.0	70.0	73.0	76.0	70.0
Policy B: v =1.0	54.0	60.0	70.0	80.0	86.0	70.0
Policy B: v =1.5	56.8	67.0	70.0	80.0	86.0	72.0
Policy B: v =2.0	60.6	67.0	70.0	80.0	86.0	72.7
Policy B: v =2.5	62.2	67.0	70.0	80.0	86.0	73.0
Policy B: v =3.0	63.0	67.0	70.0	80.0	86.0	73.2

Appendix 3.3

Table 1 Survey version and associated order of question

Version Number	*1st Question*	*2nd Question*	*3rd Question*
1	Income, IA= 1	Health, IA= 1	Bivariate, IA= 3
2	Health, IA= 1	Income, IA= 2	Bivariate, IA= 1
3	Income, IA= 3	Health, IA= 1	Bivariate, IA= 2.5
4	Health, IA= 1.5	Income, IA= 1	Bivariate, IA= 1
5	Income, IA= 1.5	Health, IA= 1.5	Bivariate, IA= 2
6	Income, IA= 2.5	Health, IA= 1.5	Bivariate, IA= 1.5
7	Health, IA= 2	Income, IA= 1	Bivariate, IA= 2
8	Income, IA= 2	Health, IA= 2	Bivariate, IA= 3
9	Bivariate, IA= 1	Income, IA= 2.5	Health, IA= 2
10	Health, IA= 2.5	Income, IA= 1.5	Bivariate, IA= 2.5
11	Bivariate, IA= 2	Income, IA= 2.5	Health, IA= 2.5
12	Bivariate, IA= 1.5	Income, IA= 3	Health, IA= 2.5
13	Health, IA= 3	Income, IA= 1.5	Bivariate, IA= 1.5
14	Bivariate, IA= 2.5	Income, IA= 2	Health, IA= 2
15	Bivariate, IA= 3	Income, IA= 3	Health, IA= 3

Notes: IA = inequality aversion

Appendix 3.4 Sample survey instrument

McMaster Economics Inequality Survey V1

Thank you for agreeing to complete this survey.

There are 50 questions in this survey

Introduction

Thank you for participating in our survey.

As a gesture of our appreciation, you will be entered into a draw for one of the $250 prizes when you complete the survey. To be eligible, please re-enter the ID Code provided to you in your letter into the space below.

Please write your answer here:

This survey contains five sections: in sections 1 - 3 we ask you some questions regarding inequality. Section 4 asks you questions about dividing money; and section 5 asks you some questions about your background, which are used for statistical purposes only. We anticipate that the survey will take 10-15 minutes to complete.

Each of sections 1 - 3 presents a scenario relating to government policies in a hypothetical country. In each case, we provide you with some basic information regarding the effects of each policy and ask which policy you would prefer to be implemented. There are no right or wrong answers to these questions. Your answers depend on your personal judgment; we ask only that you reflect carefully on your choices.

Remember, when you complete the survey, you will be entered into the draw for the $250 prizes, so we'd really like you to complete the whole survey. Thanks!

Section 1 of 5: Income Inequality

Imagine a hypothetical country in which citizens are identical in all ways except one: their incomes. The government must choose between implementing one of two policies. Both policies will have an impact on citizens' incomes. Indeed, the only impact of the policies is on the level and distribution of income within the population, though each policy affects the incomes of different groups differently. These impacts will not happen instantaneously, but will occur over the next 3-5 years.

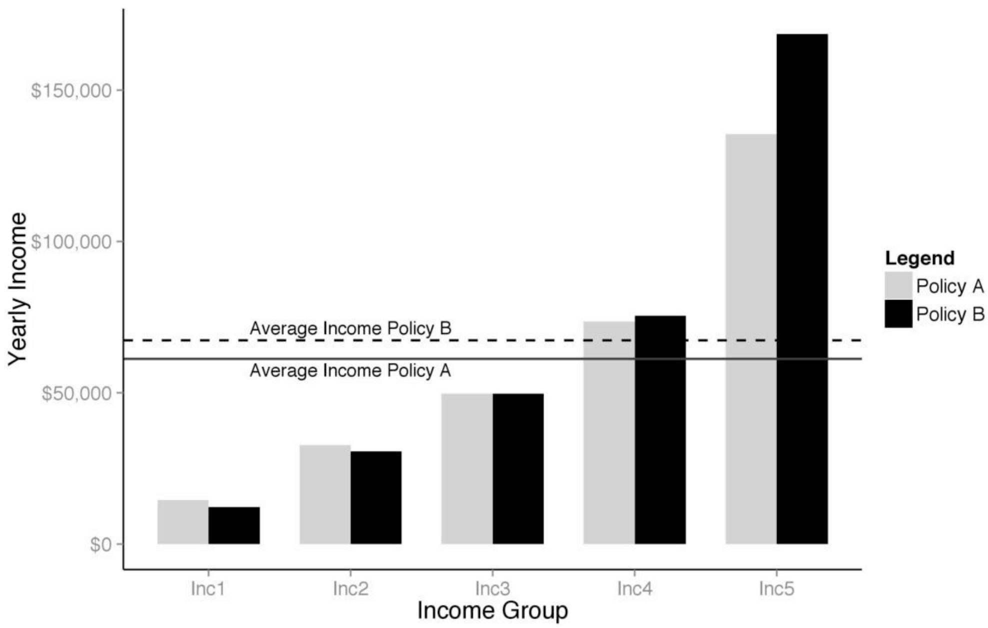
The table below presents information for each policy on the resulting yearly income for individuals in the country, after taking into account all taxes and government programs. (We present the same information in a graph below the table). In this country there are five levels of income, and the number of people with each income level is identical. In the table we label the income groups Inc1-Inc5, where Inc1 refers to the group with the lowest level of income and Inc5 refers to the group with highest level of income. Everyone within each income group has the same income, but incomes differ across the five groups.

The government must choose between the two policies listed. We ask you which of the two policies you would prefer that the government implement.

There is no right or wrong answer; we are interested in your personal judgment.

Question 1: Annual Income, by Income Group, under each of Policy A and Policy B

Income Groups (each group contains the same number of individuals)	Inc1	Inc2	Inc3	Inc4	Inc5	Average Income in the Country
Policy A	$14,600	$32,700	$49,700	$73,500	$135,500	$61,200
Policy B	$12,200	$30,700	$49,700	$75,500	$168,500	$67,320



The government will implement either Policy A or Policy B. Please indicate which policy you prefer that the government implement. *

Please choose **only one** of the following:

- ○ Policy A
- ○ Policy B

Why did you choose this policy? (Please write response in box below)

Please write your answer here:

Section 2 of 5: Health Inequality

Imagine a hypothetical country in which citizens are identical in all ways except one: their levels of health. The government must choose between implementing one of two policies. Both policies will have an impact on citizens' health. Indeed, the only impact of both policies is on the level and distribution of health within the population, though each policy affects the health of different groups differently. Note that citizens' access to health care will be the same under both policies. These impacts will not happen instantaneously, but will occur over the next 3-5 years.

The table below presents information for each policy on the resulting levels of people's health, where health is measured by health-adjusted life expectancy. (We present the same information in a graph below the table). This measure of health combines information on both how many years a person can expect to live and how healthy those years will be. For example, two people might both expect to live to 75 years. If one person lives in full health until they die suddenly of a heart attack, then their health-adjusted life expectancy would be 75 years. If the second person, however, lives the last ten years of their life with a painful chronic condition, this individual's health-adjusted life expectancy is less than 75 years (e.g., 71 years) because they suffer from the chronic condition.

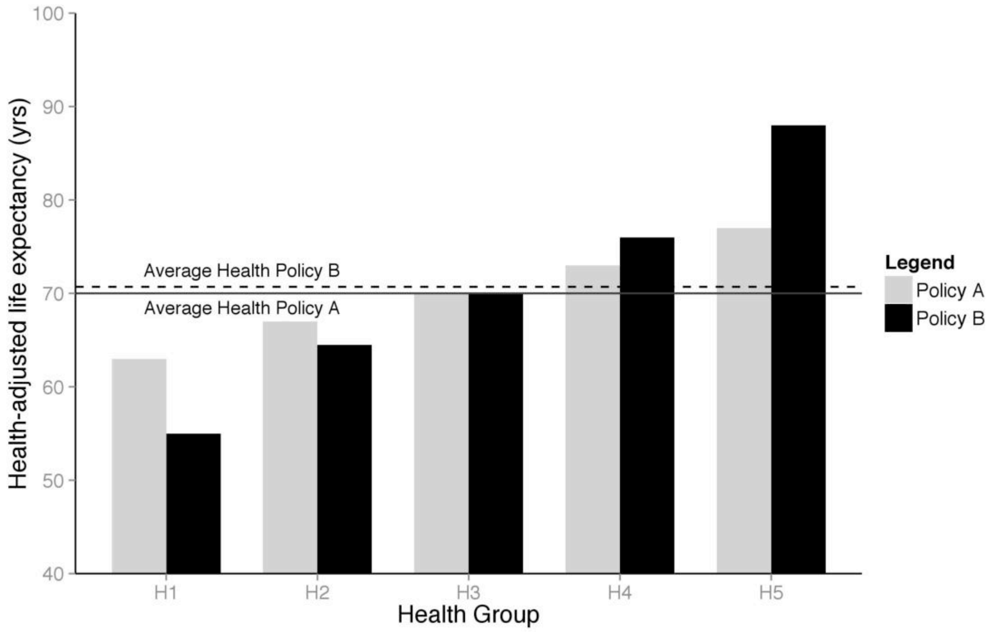
In this country there are five levels of health, and the number of people with each health level is identical. In the table we label the health groups H1-H5, where H1 refers to the group with the shortest health-adjusted life expectancy and H5 refers to the group with the longest health-adjusted life expectancy. Everyone within each group has the same health-adjusted life expectancy, but health-adjusted life expectancies differ across the five groups. To place the impact of the policies in context, average life expectancy for both Canada and the US has increased by about 1 year every decade since 1950.

The government must choose between the two policies listed. We ask you which of the two policies you would prefer that the government implement.

There is no right or wrong answer; we are interested in your personal judgment.

Queston 2: Health-adjusted life expectancy (measured in years), by Level of Health under Policies A and B

Health Groups (each group contains the same number of individuals)	H1	H2	H3	H4	H5	Average Level of Health in the Country
Policy A	63.0	67.0	70.0	73.0	77.0	70.0
Policy B	55.0	64.5	70.0	76.0	88.0	70.7



The government will implement either Policy A or Policy B. Please indicate which policy you prefer that the government implement. *

Please choose **only one** of the following:

- ◯ Policy A
- ◯ Policy B

Why did you choose this policy? (Please write response in box below)

Please write your answer here:

Section 3 of 5: Income-Related Health Inequality

Imagine a hypothetical country in which citizens are identical in all ways except two: their incomes and their health. The government must choose between implementing one of two policies. Both policies will have no impact on people's income, but will have an impact on the level and distribution of people's health. Further, this impact on health is the only impact of the policies, and the health impact depends on a person's income. Note that citizens' access to health care will be the same under both policies. These impacts will not happen instantaneously, but will occur over the next 3-5 years.

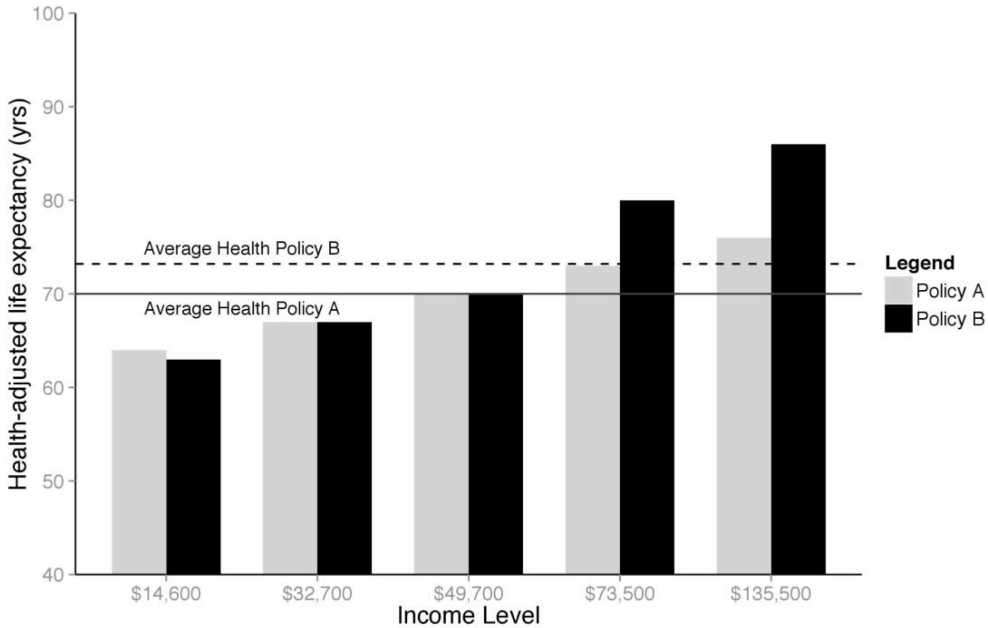
For each policy, the table below presents information, by income level, on the resulting levels of health for those with the indicated income. As in the earlier section, income is measured by annual income, after taking into account all taxes and government programs. There are five income groups in this country (Inc1 – Inc5), each income group contains the same number of people and everyone within each group has the same income but incomes differ across the five groups as indicated in the table. Similarly, as in the earlier section, health is measured by health-adjusted life expectancy. For each income group, the table provides information on people's health-adjusted life expectancy under each of the two proposed policies. Within each income group everyone has the same health-adjusted life expectancy, but the health-adjusted life expectancy differs across the income groups. Again, to place the impact of the policies in context, average life expectancy for both Canada and the US has increased by about 1 year every decade since 1950.

The government must choose between the two policies listed. We ask you which of the two policies you would prefer that the government implement.

<u>There is no right or wrong answer</u>; we are interested in your personal judgment.

Question 3: Health-adjusted life expectancy (in years), by Income level, under Policies A and B

Income Group (each group contains the same number of individuals)	Inc1	Inc2	Inc3	Inc4	Inc5	Average Level of Health in the Country
Income-level	$14,600	$32,700	$49,700	$73,500	$135,500	
Policy A	64.0	67.0	70.0	73.0	76.0	70.0
Policy B	63.0	67.0	70.0	80.0	86.0	73.2



The government will implement either Policy A or Policy B. Please indicate which policy you prefer that the government implement. *

Please choose **only one** of the following:

- ○ Policy A
- ○ Policy B

Why did you choose this policy? (Please write response in box below)

Please write your answer here:

Section 4 of 5: Money Sharing

In this section, we present some hypothetical choices about money sharing. Your choices affect the amount of money you would receive as well as the amount of money that would be received by a random person with whom you have been matched. You do not know who this other person is.

For each question we present two options and ask you to choose one. Each option describes an amount of money that you would get as well as the amount of money the other person would get.

For some options, you, the other person, or both lose money. These are indicated by negative signs (i.e. -$5.00 means a loss of $5.00). All amounts are in Canadian dollars.

Imagine that at the same time you are making your choices the other person (to whom you have been matched) is answering the same questions, making choices as to how they would split money between themselves and you.

After you have made all of your choices, the final amount of money you would hypothetically "receive" is the total of all amounts that you get from *your* choices plus the total of all amounts that you get from *the other person's* choices. Similarly, the final amount the other person would receive is the total of the amounts that you decided to give them through your choices plus the amounts that they decided to give themselves through their choices.

To help you understand, we provide an example on the next screen.

Example

Here is an example of the kind of decision you will be asked to make. Two options will appear on your computer screen.

Option A		Option B	
You Receive	Other Receives	You Receive	Other Receives
$9.70	-$2.60	$10.00	$0.00

You must select either Option A or Option B.

O: Option A
O: Option B

Explanation:

If you choose Option A, you would receive $9.70 and the other person would lose $2.60.
If you choose Option B, you would receive $10.00 and the other person would receive nothing.

We now present 24 scenarios like this example.

There are no right or wrong answers; we are interested in your personal judgment.

Scenario 1 of 24

Option A		Option B	
You Receive	Other Receives	You Receive	Other Receives
$7.10	$7.10	$5.00	$8.70

*

Please choose **only one** of the following:

- Option A
- Option B

Scenario 2 of 24

Option A		Option B	
You Receive	Other Receives	You Receive	Other Receives
-$8.70	-$5.00	-$7.10	-$7.10

*

Please choose **only one** of the following:

- Option A
- Option B

Scenario 3 of 24

Option A		Option B	
You Receive	Other Receives	You Receive	Other Receives
-$8.70	$5.00	-$9.70	$2.60

*

Please choose **only one** of the following:

- Option A
- Option B

Scenario 4 of 24

Option A		Option B	
You Receive	Other Receives	You Receive	Other Receives
$0.00	-$10.00	$2.60	-$9.70

*

Please choose **only one** of the following:

- Option A
- Option B

Scenario 5 of 24

Option A		Option B	
You Receive	Other Receives	You Receive	Other Receives
-$7.10	$7.10	-$8.70	$5.00

*

Please choose **only one** of the following:

- Option A
- Option B

Scenario 6 of 24

Option A		Option B	
You Receive	Other Receives	You Receive	Other Receives
$9.70	-$2.60	$10.00	$0.00

*

Please choose **only one** of the following:

- Option A
- Option B

Scenario 7 of 24

Option A		Option B	
You Receive	Other Receives	You Receive	Other Receives
-$2.60	-$9.70	$0.00	-$10.00

*

Please choose **only one** of the following:

- Option A
- Option B

Scenario 8 of 24

Option A		Option B	
You Receive	Other Receives	You Receive	Other Receives
-$9.70	$2.60	-$10.00	$0.00

*

Please choose **only one** of the following:

- Option A
- Option B

Scenario 9 of 24

Option A		Option B	
You Receive	Other Receives	You Receive	Other Receives
-$2.60	$9.70	-$5.00	$8.70

*

Please choose **only one** of the following:

- Option A
- Option B

Scenario 10 of 24

Option A		Option B	
You Receive	Other Receives	You Receive	Other Receives
$10.00	$0.00	$9.70	$2.60

*

Please choose **only one** of the following:

- Option A
- Option B

Scenario 11 of 24

Option A		Option B	
You Receive	Other Receives	You Receive	Other Receives
$9.70	$2.60	$8.70	$5.00

*

Please choose **only one** of the following:

- Option A
- Option B

Scenario 12 of 24

Option A		Option B	
You Receive	Other Receives	You Receive	Other Receives
$8.70	-$5.00	$9.70	-$2.60

*

Please choose **only one** of the following:

- Option A
- Option B

Scenario 13 of 24

Option A		Option B	
You Receive	Other Receives	You Receive	Other Receives
$5.00	-$8.70	$7.10	-$7.10

*

Please choose **only one** of the following:

- Option A
- Option B

Scenario 14 of 24

Option A		Option B		
You Receive	Other Receives	You Receive	Other Receives	
-$7.10	-$7.10	-$5.00	-$8.70	*

Please choose **only one** of the following:

- Option A
- Option B

Scenario 15 of 24

Option A		Option B		
You Receive	Other Receives	You Receive	Other Receives	
$2.60	$9.70	$0.00	$10.00	*

Please choose **only one** of the following:

- Option A
- Option B

Scenario 16 of 24

Option A		Option B		
You Receive	Other Receives	You Receive	Other Receives	
-$9.70	-$2.60	-$8.70	-$5.00	*

Please choose **only one** of the following:

- Option A
- Option B

Scenario 17 of 24

Option A		Option B		
You Receive	Other Receives	You Receive	Other Receives	
$8.70	$5.00	$7.10	$7.10	*

Please choose **only one** of the following:

- Option A
- Option B

Scenario 18 of 24

Option A		Option B		
You Receive	Other Receives	You Receive	Other Receives	
$0.00	$10.00	-$2.60	$9.70	*

Please choose **only one** of the following:

○ Option A
○ Option B

Scenario 19 of 24

Option A		Option B		
You Receive	Other Receives	You Receive	Other Receives	
$7.10	-$7.10	$8.70	-$5.00	*

Please choose **only one** of the following:

○ Option A
○ Option B

Scenario 20 of 24

Option A		Option B		
You Receive	Other Receives	You Receive	Other Receives	
-$5.00	-$8.70	-$2.60	-$9.70	*

Please choose **only one** of the following:

○ Option A
○ Option B

Scenario 21 of 24

Option A		Option B		
You Receive	Other Receives	You Receive	Other Receives	
$2.60	-$9.70	$5.00	-$8.70	*

Please choose **only one** of the following:

○ Option A
○ Option B

Scenario 22 of 24

Option A		Option B		
You Receive	Other Receives	You Receive	Other Receives	
$5.00	$8.70	$2.60	$9.70	*

Please choose **only one** of the following:

○ Option A
○ Option B

Scenario 23 of 24

Option A	Option B

You Receive	Other Receives	You Receive	Other Receives	
-$5.00	$8.70	-$7.10	$7.10	*

Please choose **only one** of the following:

- Option A
- Option B

Scenario 24 of 24

Option A		Option B		
You Receive	Other Receives	You Receive	Other Receives	
-$10.00	$0.00	-$9.70	-$2.60	*

Please choose **only one** of the following:

- Option A
- Option B

Section 5 of 5: Background Information

This is the last section in the survey. We'd like to collect a bit of background information that we will use for statistical purposes.

What is your sex? *

Please choose **only one** of the following:

- ○ Female
- ○ Male
- ○ Prefer not to respond

What is your year of birth?

Only numbers may be entered in this field.
Please check the format of your answer.

Please write your answer here:

[ ]

(Enter 4 digits, like 1970 or 1956)

In general would you say your health is (excellent, very good, good, fair, poor)? *

Please choose **only one** of the following:

- ○ Excellent
- ○ Very Good
- ○ Good
- ○ Fair
- ○ Poor
- ○ Prefer not to respond

What is your marital status? *

Please choose **only one** of the following:

- ○ Single (never married)
- ○ Married or Common-Law
- ○ Divorced
- ○ Widowed
- ○ Prefer not to respond

What is your current work status? *

Please choose **only one** of the following:

- ○ Full-time employment
- ○ Part-time employment
- ○ Not employed

- Retired
- Prefer not to respond

Do you own or rent your house / apartment? *

Please choose **only one** of the following:

- Own
- Rent
- Other
- Prefer not to respond

What is the highest level of education you have attained? *

Please choose **only one** of the following:

- Less than secondary school
- Secondary school graduate
- Post-secondary graduate (i.e., college, apprentice, trade diploma or certificate)
- University graduate
- Prefer not to respond

What is your best estimate of the total income (before taxes and deductions) of all household members from all sources in the past 12 months? *

Please choose **only one** of the following:

- No Income
- Less than $20,000
- $20,000 to $49,999
- $50,000 to $74,999
- $75,000 to $100,000
- More than $100,000
- Prefer not to respond

We ask for your income for statistical purposes only and will never release it to anyone.

Have you ever worked in the health care sector? *

Please choose **only one** of the following:

- Yes
- No
- Prefer not to answer

That's all the questions we have. When you click the button below, your reponse will be recorded and you will automatically be entered into the draw for one of the $250 prizes. We will contact the winners and we will also post the winning ID Codes on our website.

If you have any additional thoughts or suggestions about our study, please feel free to note them here.

Thanks again for completing our survey and helping us with our research.

Please write your answer here:

01.06.2015 – 08:52

Submit your survey.
Thank you for completing this survey.

Appendix 3.5

Table 1 Summary of final sample

	# Observations deleted	Final count
Mailed invitations		17,000
Letters returned as undeliverable*		50
Starting sample		2,667
Removing observations that logged in but did not answer a single question	309	2,358
Keeping only last of multiple logins	394	1,964
Full Sample		**1,964**
Complete subsample		1,810
Partial subsample		154

Note: *Postage stamp used did not allow for undeliverable mail.

Appendix 3.6 Post stratification weights

The purpose of post-stratification weights is to correct for known differences between the experimental sample and the population. By reweighting the data to match the Ontario age-sex distribution we can remove any systematic bias in the responses resulting from different response rates across these categories. Although, this does not mean other potential sources of bias (i.e. arising from questionnaire design, data collection) are also corrected for.

We calculate the post-stratification weights as a ratio of the Ontario population frequencies based on estimates from the Canadian Community Health Survey and cell frequencies in our survey:

Proportional weights are calculated as follows (Little 1993):

$$w_h = {}^{rP_h}/_{r_h}$$

Where w_h is the post-stratification weight calculated for post-stratum h (i.e. age categories, sex), r_h is the proportion of survey participants in post-stratum h, and rP_h is the population proportion from the Canadian Community Health survey.

Because our experimental sample consists of participants whom are older (mean age 59 yrs. versus 44 yrs. for Ontario) and we have a disproportionate number of males complete the questionnaire (77% versus 48% for Ontario) the weights for some post-stratum are large:

Table 1 Untrimmed post-stratification weights by age and sex

Age (yrs.)	*Male*	*Female*
less 35	10.5	17.8
35-49	1.0	2.3
50-64	0.3	1.2
65-79	0.3	1.6
>80	0.4	6.6

Specifically, those under the age of 35 yrs. and particularly those under the age of 35 yrs. and female have post-stratification weights several times higher than weights for other categories. We therefore trim these post-stratification weights to avoid these participants from driving the conclusions of the analysis. In fact, they are likely to be unrepresentative for their age/sex group for the very reason that they decided to participate and others (of the same age and sex categories) did not.

Trimming post-stratification weights

Large weights lead to weighted estimates that have a high variance. By trimming the large weights, we reduce the variance however at the cost of introducing bias. Weighting, in general, increases the variance of estimates, the increase in variance can overwhelm the decrease in bias, hence weight trimming can be worthwhile.

We trim post-stratification weights by reducing the large weights to a fixed (arbitrarily chosen in our case) cut-point value and adjust the weights below that cut-point value to maintain untrimmed weight sum (Elliot M.R and Little R.J.A. (2000)). The table below displays the resulting trimmed weights used in the analysis.

Table 2 Trimmed post-stratification weights by age and sex

Age (yrs.)	*Male*	*Female*
less 35	7.0	7.0
35-49	2.7	6.4
50-64	1.0	3.5
65-79	0.7	4.5
>80	1.2	7.0

Appendix 3.7

Table 1 Predicted probability of choosing more equal distribution across income, health, bivariate (All Response Data)

	Income		Health		Bivariate	
	Coefficient	Coefficient (weighted)	Coefficient	Coefficient (weighted)	Coefficient	Coefficient (weighted)
Income question asked first, followed by health	0.114***	0.134***	-		-	
	(0.026)	(0.017)				
Health question asked first, followed by income	-		-0.096***	-0.104***	-	
			(0.026)	(0.018)		
Bivariate question asked first, followed by income	-		-		0.008	-0.007
					(0.025)	(0.017)
ε =1.0	ref		ref		ref	
ε =1.5	-0.076	-0.077**	0.016	0.016	-0.166***	-0.176***
	(0.039)	(0.027)	(0.04)	(0.028)	(0.038)	(0.026)
ε =2.0	-0.077*	-0.075**	0.008	0.002	-0.255***	-0.239***
	(0.039)	(0.026)	(0.037)	(0.025)	(0.036)	(0.025)
ε =2.5	-0.129***	-0.142***	-0.004	-0.031	-0.416***	-0.445***
	(0.039)	(0.026)	(0.04)	(0.027)	(0.035)	(0.024)
ε =3.0	-0.135***	-0.115***	-0.016	-0.003	-0.380***	-0.361***
	(0.039)	(0.026)	(0.045)	(0.031)	(0.036)	(0.025)
Age > 60 yrs.	0.057	0.057**	-0.063*	-0.021	-0.026	-0.004
	(0.03)	(0.021)	(0.031)	(0.021)	(0.03)	(0.021)
Female	0.086**	0.098***	-0.002	0	0.038	0.049**
	(0.031)	(0.017)	(0.031)	(0.017)	(0.03)	(0.017)
Poor health	0.024	0.048**	-0.008	-0.028	0.033	0.034
	(0.026)	(0.018)	(0.027)	(0.018)	(0.025)	(0.017)
High education	-0.084***	-0.096***	0.075**	0.049**	-0.019	-0.026
	(0.025)	(0.017)	(0.026)	(0.018)	(0.025)	(0.017)
	-0.038	-0.026	-0.053	-0.057**	-0.024	-0.045*
FT employed	(0.031)	(0.02)	(0.031)	(0.021)	(0.03)	(0.02)

	-0.02	-0.012	-0.031	-0.021	-0.085**	-0.053**
Income ≥ 75K	(0.028)	(0.019)	(0.029)	(0.02)	(0.028)	(0.019)
	0.078**	0.079***	0.102***	0.134***	0.085**	0.108***
Coop./Alt.	(0.027)	(0.018)	(0.027)	(0.019)	(0.027)	(0.018)

Notes: * p<0.05, ** p<0.01, *** p<0.001. Estimates are average marginal effects. Standard errors in parenthesis. Poor health defined as self-assessed health as good, fair or poor, reference category is good health defined as self-assessed health as very good, or excellent; high education defined as university graduate, reference category is low education defined as post-secondary graduate, less than secondary and secondary school graduates; FT employed denotes full-time employment, reference category is non-FT which includes part-time, not-employed, or other employment; Coop.Alt. denotes cooperative or altruistic value orientation, reference category is Agg./Comp./Ind./Other denotes aggressive, competitive, individualistic or other social value orientation.

Appendix 3.8

Table 1 Weighted proportion of participants choosing each policy option across the assumed inequality aversion values

Domain	N	IA	More Equal Distribution* % (1)	95% CI	Less equal Distribution ‡ % (2)	95% CI
Income	124	1.0	73.66	[67, 79]	26.34	[21, 33]
	135	1.5	72.95	[67, 78]	27.05	[22, 33]
	136	2.0	66.80	[61, 72]	33.20	[28, 39]
	140	2.5	56.02	[50, 62]	43.98	[38, 50]
	136	3.0	65.93	[60, 71]	34.07	[27, 40]
Health	122	1.0	48.88	[42, 55]	51.12	[45, 58]
	130	1.5	56.54	[50, 63]	43.46	[37, 50]
	139	2.0	48.33	[43, 54]	51.67	[46, 57]
	135	2.5	40.77	[35, 47]	59.23	[53, 65]
	124	3.0	49.80	[44, 56]	50.20	[44, 56]
Bivariate	132	1.0	79.01	[74, 84]	20.99	[16, 26]
	124	1.5	54.66	[48, 61]	45.34	[39,52]
	130	2.0	41.20	[36, 47]	58.80	[53, 64]
	130	2.5	28.57	[23, 35]	71.43	[65, 77]
	127	3.0	40.91	[35, 47]	59.09	[53, 65]

Notes: *The more equal distribution has a lower mean but also lower variance. ‡ The less equal distribution has a higher mean but also higher variance.

Appendix 3.9

Table 1 Weighted structural estimates of the mean inequality aversion estimates for income, health, and the bivariate distribution of income-related health inequality

	Income distribution		Health distribution		Bivariate distribution	
	ϵ	$\ln(\sigma)$	ϵ	$\ln(\sigma)$	ϵ	$\ln(\sigma)$
Overall	3.27***	-23.55***	1.39***	-3.01	1.61***	0.83***
	(0.52)	(4.95)	(0.46)	(2.23)	(0.05)	(0.09)
Age ≤ 60 yrs.	3.28***	-24.09***	1.19***	-3.19**	1.97***	0.86***
	(0.83)	(7.93)	(0.29)	(1.48)	(0.14)	(0.17)
Age > 60 yrs.	3.27***	-23.23***	3.33	-9.21	1.49***	0.79***
	(0.70)	(6.70)	(15.54)	(58.08)	(0.05)	(0.10)
Females	3.33***	-24.60***	1.42***	-4.10***	1.80***	1.00***
	(0.57)	(5.43)	(0.25)	(1.21)	(0.11)	(0.16)
Males	3.21***	-22.50**	-	-	1.51***	0.71***
	(0.98)	(9.34)			(0.06)	(0.11)
Poor health	3.32***	-24.00***	1.74***	-4.84**	1.61***	0.48***
	(0.81)	(7.70)	(0.58)	(2.38)	(0.06)	(0.12)
Good health	3.22***	-23.07***	1.07	-1.63	1.61***	1.05***
	(0.65)	(6.19)	(0.72)	(3.69)	(0.08)	(0.13)
High Education	3.03***	-21.28**	4.22	-14.27	1.58***	0.53***
	(1.00)	(9.47)	(5.13)	(19.90)	(0.06)	(0.10)
Low Education	3.32***	-23.98***	0.19	2.02	1.63***	1.10***
	(0.61)	(5.81)	(1.30)	(6.32)	(0.09)	(0.16)
FT employed	3.33***	-23.66***	1.67***	-5.41***	1.43***	0.75***
	(0.94)	(8.95)	(0.21)	(0.87)	(0.05)	(0.11)
non-FT	3.22***	-23.63***	-	-	2.01***	0.88***
	(0.59)	(5.58)			(0.14)	(0.15)
Income < 75K	3.42***	-25.62***	0.00	2.94***	1.80***	0.68***
	(0.58)	(5.54)	(0.01)	(0.51)	(0.10)	(0.16)

Income ≥ 75K	3.10***	-21.71***	4.21	-14.00	1.45***	0.86***
	(0.75)	(7.18)	(6.24)	(24.16)	(0.06)	(0.11)
Coop./Alt.	3.22***	-23.25***	2.80**	-9.03**	1.66***	0.79***
	(0.51)	(4.87)	(1.26)	(4.54)	(0.06)	(0.10)
Agg./Comp./Ind./Other	3.54*	-25.62	-	-	1.50***	0.95***
	(2.05)	(19.54)			(0.10)	(0.18)

Notes: * p<0.05, ** p<0.01, *** p<0.001. Standard errors in parenthesis. σ represents the standard deviation of the inequality aversion parameter.With the exception of 'Overall', split-sample models were estimated. Poor health defined as self-assessed health as good, fair or poor; good health defined as self-assessed health as very good, or excellent; high education defined as university, low education defined as post-secondary graduate, less than secondary and secondary school graduates. FT denotes full-time employment; non-FT denotes part-time, not-employed, or other employment; Coop.Alt. denotes cooperative or altruistic value orientation; Agg./Comp./Ind./Other denotes aggressive, competitive, individualistic or other social value orientation.

Appendix 3.10 Latent class structural model

To further examine the bi-modal distribution of preferences in IA towards the health distribution we extend the structural model into a latent class (LC) setting (Hurley et al., 2017). In doing so, the independence of irrelevant alternatives (IIA) assumption underlying the structural models is partially relaxed. The LC models probabilistically sort participants into C classes with each class representing a different preference pattern (Cameron and Trivedi, 2005). Class membership follows a multinomial logistic distribution where the probability that individual *i* falls in class *c* is denoted by

$$H_{ic} = \frac{e^{z_i \gamma_c}}{\sum_{c=1}^{C} e^{z_i \gamma_c}} \qquad (13)$$

where z_i are individual specific covariates that characterize the class membership. The contribution of individual *i* to the likelihood is denoted by

$$L_i = \sum_{c=1}^{C} H_{ic} \times P(A_i) \qquad (14)$$

and the log-likelihood for sample size N is denoted by

$$\ln L = \sum_{i=1}^{N} ln[\sum_{c=1}^{C} H_{ic} \times P(A_i)] \qquad (15)$$

To resolve convergence issues in the LC models we exploit the relative nature and scale invariance that the Atkinson function exhibits and transform v_{iA}-v_{iB} from equation (4) to capture the relative, as opposed to the absolute, distance between the two presented distributions. This reformulation in the non-LC models results in identical ϵ values (up to the fifth decimal) to the original model. The LC model is estimated through the Expectation Minimization (EM) algorithm because it offers greater stability compared to maximum likelihood estimation. The steps of the EM algorithm for a latent class binary model are discussed in detail in De Soete and DeSarbo, (1991). Standard errors for the EM estimation are calculated using bootstrap methods with 250 replications.

Appendix 3.11 Equally distributed equivalent calculations

The equally distributed equivalent (EDE) is the amount of income/health that, if equally distributed, would result in the same utility as the initial distribution of income/health.

The EDE can be calculated as:

EDE= $\bar{y}$*(1-A)

Where $\bar{y}$ is the mean income/health and A is the Atkinson index of inequality.

The Atkinson index of inequality is:

$$A = 1 - \left[\frac{1}{n}\sum_{i=1}^{N}\left[\frac{y_i}{\bar{y}}\right]^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} \quad for\ \varepsilon \neq 1$$

The Atkinson index of inequality can be interpreted as the maximum proportion of income/health that society is willing to give up if the remainder is equally distributed.

The baseline income distribution, assuming $\varepsilon = 3.27$

	Quintile	Average income ($)	$\left[\frac{y_i}{\bar{y}}\right]^{1-\varepsilon}$	$\frac{1}{n}\sum_{i=1}^{N}\left[\frac{y_i}{\bar{y}}\right]^{1-\varepsilon}$	$1 - \left[\frac{1}{n}\sum_{i=1}^{N}\left[\frac{y_i}{\bar{y}}\right]^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}$
	Q1	14,600	$\left[\frac{14,600}{61,200}\right]^{1-3.27}$ =25.87		
	Q2	32,700	4.15		
	Q3	49,700	1.60		
	Q4	73,500	0.66		
	Q5	135,500	0.16		
Mean income		61,200		6.49	

Atkinson Index					**0.561284**
EDE					26,849.42

The baseline HALE distribution, assuming $\varepsilon = 7.3$

	Quintile	Average HALE	$\left[\frac{y_i}{\bar{y}}\right]^{1-\varepsilon}$	$\frac{1}{n}\sum_{i=1}^{N}\left[\frac{y_i}{\bar{y}}\right]^{1-\varepsilon}$	$1-\left[\frac{1}{n}\sum_{i=1}^{N}\left[\frac{y_i}{\bar{y}}\right]^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}$
	Q1	63	$\left[\frac{63}{70}\right]^{1-7.3}$ =1.94		
	Q2	67	1.32		
	Q3	70	1.00		
	Q4	73	0.77		
	Q5	77	0.55		
Mean income		70		1.12	
Atkinson Index					**0.017162**
EDE					68.80

Appendix 3.12

Table 1 Common themes for choosing the more equal distribution with sample quotes

Income themes	Sample quote	Health themes	Sample quote	Bivariate themes	Sample quote
Concern for lowest quintile	"I felt it was more important to help the poorer two income levels than the richer two levels even if it meant that the average income would go down." "The fact that Inc 2,3 and 4 remained the same actually made me prefer neither. But benefiting the lowest group (even modestly) seems more useful than benefiting the highest group (by such a vast amount)"	Concern for lowest quintile	"I believe in fairness. We should be judged by how we treat the least fortunate among us. I believe it best to increase the minimum life expectancy or health level so that the least healthy will have an increased life expectancy." "More beneficial for those in the lowest two groups, who usually are also the poorest. No change in the middle. Assume those in the healthiest range are there because of a combination of genetics and good economic fortune"	Concern for lowest quintile	“There is a significant adverse difference in life expectancy for the lowest income bracket if Policy B were to be implemented but the overall average difference between the two policies is minimal.” “People of a lower income contribute as much to society as higher income people and are just as cared about by their family"s. how can a government in good conscience implement a policy that benefits 2 of 5 segments , and at the expense of 1

					segment”
Better outcomes for the for the lower quintile groups and this is good for society/economy	"Societies are better off with less poverty. When lower income earners increase their income there is more economic activity than with lower incomes. The incidence of poverty is reduced and people live better, more healthy lives.”	Better outcomes for the lower quintile groups and this is good for the economy/society	"Group H1 enjoys a significant increase in expectancy in "prime" living years. They are still contributing productive members of society. An average age of 77 (vs 88) for group H5 doesn't warrant the dramatic difference in group H1." "Policy A has a greater impact on the H1-H2 groups. If the health can be improved in these groups perhaps these individuals would cost our government less dollars and in fact these individuals could contribute to society"	Concern for the lowest quintile groups because they are in greater need	“This was actually a harder choice than I thought. Ultimately, it seemed unethical to choose a plan that would deprive the neediest sector of the population of adequate health coverage”
Concern for the lowest quintile groups because they are in greater	"Policy A puts more money in the pockets of those who need it most,	Benefits more of society	"Because I think that Policy A would raise the level of health for more people	Everyone, irrespective of income, should have access to	I don't believe it is correct that the more money you make, the longer you live.

need	and less in the pockets of those who don't." "Policy A redistributes wealth to the most needy. It reduces income disparity which could ease social tension (envy, etc.) and produce a fairer society"		even though some would not be raised to as high a level as possible." "It seemed that policy A would help ensure that all members (or more) of the population have an improved life expectancy. It seems to distribute the health benefits to more people, rather than concentrate them to H4 and H5"	good health	In a democratic society, policy should not favour the rich, especially when the stakes are the highest possible--longer life. “Health is one of those things that everyone should have equal access/rights to. The higher income levels can compensate for policy shortcomings by purchasing private healthcare whereas the lower income group has no other option.”
More fair	"Basic fairness. Policy B increases the average income of the country but widens the gap between poor and rich, and is basically a gift to the Inc5 group."	More fair	"If universality is the objective of the hypothetical government Policy A would appear to be fairer across the five groupings” “It seems to me that policy A is more fair	More fair	“As a Christian I chose A. Though as a capitalist I did consider B. On average there is equal suffering from health reasons in both policies so choosing A is about fairness to

	"It seems closer to "fair" that Inc5 would get $135K instead of $166K, given that all the citizens are the same in all the groups."		to everyone in general. Policy B reduces the life expectancy of H1 and H2 while increasing it for H4 and H5. The best decision is one that helps many people instead of helping only some people"		individuals vs societal fairness" "Policy A appears to help people because they are people and not because of income. I see that as being more fair."
Alternative policy disproportionately benefits the highest income group only	"Policy A is preferred. Although more discretionary income is generally a good thing in the economy, Policy B provides only for the wealthiest citizens." "Although under Policy B the overall average income of the country rises, the increasing average resides primarily with the one	More equal/even/better distribution/ less discrepancy	"While Policy B improves the overall average slightly more, Policy A is more even-handed in its distribution of effect. From an ethical standpoint, I feel it is more important for a government to create substantial benefit for ~each~ of its citizens" "Because Policy A results in the most consistent improvement across all five groups which	More equal/smaller range/ more consistent/less disparity/ more even	"Neither policy is a perfect answer, but Policy A appears to reduce health adjusted life expectancy differences between the groups for all income levels. "Due to the fact that all income groups have the same amount of people, then, for the sake of equality, it would be best to even out the average life expectancy, otherwise, a fifth of

	highest income group which is not equitable nor, I believe, beneficial to the country as a whole".		I believe is an appropriate goal for governments. Policy B could be seen as creating bigger winners, but also bigger losers."		the population would have a significantly lower life expectancy"
More equitable, more even, smaller range, less disparity	"Policy B is appealing in that the average income is higher which ideally means a better economy. However, Policy A has less of a gap in the incomes. Since all citizens are the same in every way (except income), this only seems fair". "With the reason of the difference of incomes unknown, the less difference the better"	More equal/even/better distribution/ less discrepancy and this is good for the economy/society	"seems that policy A would benefit the potentially most productive members" " This is more equitable in terms of health across the population, and sound as economic policy as it keeps the bulk of the working-age adults in good health through to retirement age. The 'lost' .7 year average additional lifespan is taken large"	Alternative benefits rich at the expense of the poor	"Policy B affects those who can't use their income to personally improve their health. Policy B makes the rich better off which is contrary to what a government's objective should be" "Because I don't believe that wealthy people should live longer at the expense of the poorest and most vulnerable members of our society"
				Benefits more people	"More benefit for more people. The

		richer still live longer - just not as long as policy A, but everyone else does better too.”

Table 2 Common themes for choosing the more unequal distribution with sample quotes

Income themes	Sample quote	Health themes	Sample quote	Bivariate themes	Sample quote
Higher average	"Policy B have higher average income which I think is good for the overall economics" "Policy should always strive to increase incomes."	Higher average	"Average live expectancy increased. Lowest group lost a smaller amount than the highest. Even though it is hard on the lowest, the overall life expectancy increased. It might be differant if I knew which group I was part of." "Average health with Policy B is higher overall, thus increasing overall quality of health + H1 & H2 groups can use best knowledge gain of H4 and H5 groups"	Higher average	"Upside: the average level of health is higher with Policy B. Downside: the poorer you are the less healthy you'll be. Better to go for overall national health; this should , over the long term, free up resources to deal with the health issues" "The average life-expectancy is higher, taking into account all income brackets, so it is fair. I believe in the utilitarian principle which suggests that the higher benefit given to the

					majority is the preferred option."
Higher average and this is good for society/economy	"Average income for policy B higher which results in greater GDP for the country. Policy B also offers a higher potential to attract and retain high performance individuals." "Overall, the change in average income is negligible and neither policy narrows the gap for the low to middle income groups. Adding income to the higher income group will increase their tax brackets which fund social	Opportunity to live longer	One assumes that a government's goal is to increase the health and longevity of its population. Policy B tends toward a longer life expectancy for groups H3-5. Advances in health care can improve H1 and H2 to "catch-up"." "Greater opportunity for living healthy above average Policy B would give individuals a longer health-adjusted life expectancy while offering the same level of access to healthcare as in policy A."	Opportunity to live longer	"Better and longer life is preferable to less. In Policy B, the greaest good for the total population, even though the lowest income is adversely affected." "Good health, leading to a longer life is in of itself a form of wealth. Live longer and heatlhier."

	programs for the lower income"				
Opportunity for higher income creates an incentive to work hard	"FREEDOM TO EARN THE INCOME YOU WANT TO, AS LONG AS YOU WORK HARD AND HONEST FOR IT" "People need an incentive to improve their lives; if working harder doesn't benefit them, they will become complacent."	Benefits the healthier and they should have the opportunity to live longer	" There is a good prospect of longer life for the older age group-resulting from good lifestyle choices in their younger years-diet, exercise…" "People that are health conscious should have the opportunity to live longer with support from government policies. This is the equivalent to health capitalism."	Higher income earners will live longer and this is good for the economy/society	"Higher income earnings living longer will provide more economic return over a longer period of time" "If the govt wants wealthier people to live longer and continue to contribute their money to the economy, then B would enable people to have longer health adjusted life expectanc"
Opportunity for higher income	"with inflation need more income. Although income are slightly lower in brackets 1 and 2, the overall	Benefits more people	" My preference is an emphasis on an even or longer health adjusted life expectancy in three groups rather than just one group plus	Gains in life expectancy outweigh losses to lower income	By choosing policy B only the lower group is affected by 2 years. Everyone else lives longer or the same

	country income is higher in Policy b" "Inc5 has the ability to earn more income. In a free democratic society we all should have the opportunity to earn as much as possible."		a small difference in the second group." "I would prefer a higher level of health for all citizens, rather than a small group having a longer life. QUALITY OF LIFE is much more important to me than longevity. Death is inevitable"		length of time Although police A would benefit those in the lower income bracket, this benefit is not as significant as that when looking at the improvement in life expectancy for the higher income bracket that policy B appears to provide.
Higher overall income is good for the economy	"more income to individuals means more income tax to government. Creates more wealth to be redistributed to expand the economy" "The total income in Society will	A more realistic health distribution	" DIFFERENT PEOPLE HAVE DIFFERENT HEALTH ISSUES. POLICY IS MORE REALISTIC IN TERMS OF EXPECTATIONS" " The reality is, that human beings have a longer expectation of life,	Benefits more people	“B benefited the greater number of people - I would have had a different answer if the groups were different, e.g., if group one had 60% of the population and the last group 1 per cent” “Better and

	increase. Over time this should allow for a redistribution of the income as it flows through Society. In order to raise the level of income of those in the lower brackets other policies could be implemented."		not necessarily healthier but the technology in health fields allows the individuals to perform better facing some illness."	longer life is preferable to less. In Policy B, the greaest good for the total population, even though the lowest income is adversely affected."
Benefits to higher quintile outweigh loss to lower quintile	"Positive impact (in % terms) on higher income group is significantly greater than the negative impact on the lower income group. Higher average income" "The lowest income group is worse off by a trivial amount, while the highest			

	income group is much better off. The highest income group will probably turn around and give more to charity and of course spend more, benefiting some people in the other"		

Appendix 3.13

Table 1 Predicted probability of choosing the more equal distribution across income, health, and bivariate (marginal effects at the mean)

	Income		Health		Bivariate	
	Coefficient	Coefficient (weighted)	Coefficient	Coefficient (weighted)	Coefficient	Coefficient (weighted)
ε =1.0	reference		reference		reference	
ε =1.5	-0.027	0.03	0.042	0.115*	-0.268***	-0.289***
	(0.069)	(0.048)	(0.074)	(0.052)	(0.074)	(0.051)
ε =2.0	-0.062	-0.065	0.031	0.072	-0.412***	-0.402***
	(0.071)	(0.048)	(0.07)	(0.048)	(0.074)	(0.049)
ε =2.5	-0.214**	-0.165***	-0.041	-0.047	-0.556***	-0.564***
	(0.069)	(0.048)	(0.073)	(0.053)	(0.075)	(0.051)
ε =3.0	-0.131	-0.063	-0.03	0.058	-0.502***	-0.442***
	(0.07)	(0.047)	(0.073)	(0.051)	(0.076)	(0.051)
Age > 60 yrs.	0.006	-0.01	-0.105	-0.064	0.056	0.063
	(0.051)	(0.037)	(0.056)	(0.038)	(0.061)	(0.043)
Female	0.131*	0.146***	-0.023	-0.033	0.052	0.080*
	(0.056)	(0.029)	(0.056)	(0.033)	(0.06)	(0.032)
Poor health	0.062	0.059	0.072	0.013	-0.002	0.011
	(0.047)	(0.034)	(0.047)	(0.033)	(0.049)	(0.033)
High education	-0.048	-0.115***	0.119*	0.086*	0.009	0.012
	(0.043)	(0.029)	(0.048)	(0.034)	(0.048)	(0.033)
FT employed	-0.041	-0.045	-0.03	-0.038	-0.055	-0.124**
	(0.05)	(0.034)	(0.057)	(0.038)	(0.062)	(0.042)
Income ≥ 75K	-0.093	-0.079*	0.002	0.008	-0.110*	-0.067
	(0.049)	(0.033)	(0.052)	(0.036)	(0.054)	(0.037)
Coop./Alt.	0.052	0.064*	0.097	0.192***	0.045	0.057

	(0.047)	(0.032)	(0.051)	(0.036)	(0.051)	(0.035)

Notes: * p<0.05, ** p<0.01, *** p<0.001. Standard errors in parenthesis. Poor health defined as self-assessed health as good, fair or poor, reference category is good health defined as self-assessed health as very good, or excellent; high education defined as university graduate, reference category is low education defined as post-secondary graduate, less than secondary and secondary school graduates; FT employed denotes full-time employment, reference category is non-FT which includes part-time, not-employed, or other employment; Coop.Alt. denotes cooperative or altruistic value orientation, reference category is Agg./Comp./Ind./Other denotes aggressive, competitive, individualistic or other social value orientation.

Chapter 4 Availability and affordability of blood-pressure lowering medicines and the effect on blood pressure control in an analysis of the PURE study data

Preface:

This chapter has been published in the Lancet Public Health. I had the primary responsibility of writing this paper and conducted the statistical analyses. Salim Yusuf conceived and initiated the PURE study, supervised its conduct and data analysis, reviewed and revised all drafts of this manuscript, and oversaw my work. Martin McKee reviewed and commented on the drafts. Sumathy Ranjarian coordinated the worldwide study and reviewed and commented on manuscript drafts. All other authors coordinated the worldwide study and reviewed and commented on drafts. All authors approved the final draft.

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Summary

Background: Hypertension is considered the most important risk factor for cardiovascular diseases, but its control is poor worldwide; the reasons are poorly understood. We relate the availability and affordability of blood pressure (BP) lowering medicines in 20 countries to use of these medicines and BP control.

Methods: Availability (present in pharmacies), costs, and affordability (less than 20% of the households' capacity-to-pay) of BP lowering medicines were recorded from 626 communities in 20 countries participating in the Prospective Urban Rural Epidemiological (PURE) study and were related to use of these medicines and BP control using multilevel, mixed-effects logistic regression models.

Findings: The availability of two or more classes of BP lowering drugs was lower in low and middle-income countries (except for India) compared to high-income countries. The proportion of communities that had four drug classes available was 94% in high-income countries, 76% in India, 71% in upper-middle income countries, 47% in low-middle income countries, and 13% in low-income countries. The proportion of households unable to afford two BP lowering medicines was 31% in low-income countries, 9% in middle-income countries, and < 1 % in high-income countries. Participants with known hypertension in communities that had all four drug classes available were more likely to use at least one BP lowering medicine (adjusted OR=2·23, p<0·001, 95% CI (1·59, 3·12)), use combination therapy (adjusted OR=1·53, p<0·01, 95% CI (1·13, 2·07)), and have their BP controlled (adjusted OR= 2·06, $p<0·001$, 95% CI (1·69, 2·50)) relative to those in communities where BP lowering medicines were not available. Participants with known hypertension from households able to afford four BP lowering drug classes were more likely to use at least one BP lowering medicine (adjusted OR=1·42, $p<0·001$, 95% CI (1·25,1·62)), combination therapy (adjusted OR=1·26, $p<0·01$, 95% CI (1·08, 1·47)), and have BP controlled (adjusted OR=1·13, 95% CI (1·00, 1·28)) relative to those unable to afford the medicines.

Interpretation: A large proportion of communities in low and middle-income countries do not have access to multiple BP lowering medicines, and when available, they are often not affordable. These are associated with poor BP control. Ensuring access to affordable BP lowering medicines is essential to controlling hypertension in low and middle-income countries.

Funding: funding sources listed at end of paper.

Introduction

Hypertension affects one billion people and is a major risk factor for cardiovascular diseases (CVD) (Olsen et al., 2016). Although blood pressure (BP) lowering medicines reduce CVD events, renal failure, and mortality (Messerli et al., 2007), their use is suboptimal and BP control is poor (Chow et al., 2013).

Most individuals with hypertension require at least two BP lowering medicines to adequately control their blood pressure (Cushman et al., 2002). Diuretics, angiotensin-converting enzyme (ACE) inhibitors, calcium-channel blockers, and ß-blockers have each been shown to reduce CVD (James et al., 2014) and are the most commonly used BP lowering medicines. However, use of combination therapy is suboptimal particularly in low and middle-income countries (Chow et al., 2013). Moreover, although BP lowering medicines are listed on the WHO Model list of Essential Medicines (World Health Organization, 1977), little is known about their availability and affordability and their relationship to hypertension control. About one in four people with hypertension also have diabetes (Gress et al., 2000; Mancia, 2005) and recent trials indicate that statins double the benefit of BP lowering drug therapy by further reducing CVD events (Lonn et al., 2016; Yusuf et al., 2016a). Therefore, optimal management would include a combination of at least two BP lowering medicines, a statin, and added antidiabetic drug (when needed).

In this paper, we describe the availability and affordability of the four common classes of BP lowering medicines, statins and metformin in 20 countries at varying levels of economic development.

Methods

Study design and participants

The Prospective Urban Rural Epidemiological (PURE) study recruited 181,162 individuals between the ages of 35-70 years. Here, we report the findings from an analysis of the first phase which included 158,247 individuals from 110,677 households living in 626 communities in 20 countries, for whom a full set of data required for this analysis are currently available. Participant enrollment began in January, 2003; most communities were recruited between January 2005, and December, 2009 and the process is still continuing as new countries join. The countries and communities were selected purposively with the aim of obtaining a socio-economically and culturally diverse study sample. Within participating communities, the goal was to enrol a representative sample of households while also ensuring feasibility of long-term follow-up (Teo et al., 2009). Although not designed to be nationally representative, we have previously shown that the characteristics and death rates of the enrolled participants were similar to their national populations (Corsi et al., 2013). A comprehensive description of study design, sampling, recruitment practices and participant characteristics has been previously published and is also available in the appendix (Teo et al., 2009; Yusuf et al., 2014, 2011).

We categorised countries into four groups on the basis of the World Bank classification at the time the PURE study started (2006). The countries include four high-income countries (Sweden, United Arab Emirates, Canada and Saudi Arabia); seven upper middle-income countries (Poland, Turkey, Chile, Malaysia, South Africa, Argentina, and Brazil); four lower middle-income countries (Colombia, Iran, China, and the occupied Palestinian territory); and five low-income countries (Pakistan, Bangladesh, Zimbabwe, Tanzania and India). Data for India are presented separately as it has a large generic pharmaceutical industry and previous work has shown that availability of medicines is higher in India than in other countries at the same economic level (Khatib et al., 2016).

Ethics committees at each participating centre approved the protocol (Corsi et al., 2013; Teo et al., 2009; Yusuf et al., 2014) and all participants provided written informed consent (Teo et al., 2009).

Data collection

Availability and prices of BP lowering medicines were collected by research staff from one pharmacy in each community using the Environmental Profile of a Community's Health (EPOCH) instrument. The EPOCH instrument, a reliable and validated tool developed for measuring aspects of the environment that influence cardiovascular risk factors, has been described elsewhere (Chow et al., 2010; Corsi et al., 2012; Khatib et al., 2016). Briefly, communities with at least 30 PURE participants were included in EPOCH, which has two parts, direct observation of the physical and commercial environment and a survey of perceptions of the environment by those living in it.

In the direct observation component, the pharmacy closest to the pre-specified central location, was visited by research staff to collect information about the availability of medicines and their prices between Jan 1, 2009, and April 19 2016. We collected information regarding the availability and price of three widely used ACE-inhibitors (captopril, enalapril, and ramipril), two ß-blockers (atenolol and metoprolol), one calcium-channel blocker (amlodipine) and one diuretic (hydrochlorothiazide). Many patients with hypertension also have cardiovascular disease, diabetes or have other indications for statins (Sowers et al., 2001). We therefore present the availability and price of two widely used statins (atorvastatin, simvastatin) and metformin (commonly used for diabetes).

In the community survey component, trained interviewers collected data from all households and individuals participating in the PURE study using standardised questionnaires. Information on monthly household income and food expenditure was obtained from a knowledgeable member in each household. Names of all medicines taken at least once per week in the past month by all PURE participants were recorded by direct inspection of medicines or prescriptions. Medicines were then coded in the central project office and categorized by drug classes.

Sitting blood pressure was measured twice after a 5-minute rest period for all PURE participants by trained research assistants using a standardized procedure with an Omron digital blood pressure measuring device (Omron HEM-757). Individuals were considered hypertensive if they reported having a hypertension diagnosis and receiving blood pressure lowering treatments, or if the average of two systolic blood pressures was at least 140 mm Hg or the average of two diastolic blood pressures was at least 90 mm Hg. Individuals considered as ‘known hypertensives’ are the proportion of all hypertensives aware of their diagnosis. Individuals with known hypertension whose systolic and diastolic blood pressures were less than 140/90 mm Hg were considered to have ‘controlled hypertension”.

Definition of availability and affordability

BP lowering medicines were considered available if they were physically present in the local pharmacy surveyed on the day of data collection (Khatib et al., 2016). Total monthly costs of the medicines were estimated using standard doses and recommended frequencies (appendix). The medicines were considered affordable if total monthly costs of the lowest cost medicine(s) was less than 20% of household monthly capacity-to-pay, consistent with the literature on catastrophic health expenditure (Xu et al., 2003) and our earlier work (Khatib et al., 2016). Capacity-to-pay was estimated by subtracting basic subsistence needs, which we defined as household expenditure on food, from monthly household income. In a sensitivity analysis, we also subtracted household expenditure on housing (defined as expenditures on rent, mortgage, and utilities) and transportation (defined as expenditures on public transit fares and personal vehicle) in addition to expenditure on food, from monthly household income in a subset of PURE participants for whom such data are currently available (N = 23, 888 households, results in appendix). We present equivalised capacity-to-pay whereby capacity-to-pay estimates were divided by the square root of the household size to allow for inter-household comparisons. Household incomes, expenditures, and medicine costs were converted from their local currencies into 2010 US dollars, (after adjusting for inflation (The World Bank, n.d.)), using purchasing power parities from the World Bank (The World Bank, n.d.). We also conducted sensitivity analyses for thresholds ranging from 10% to 40% of household capacity-to-pay (see appendix). We have previously shown, in Khatib et al. (2016), that household capacity-to-pay is strongly correlated with a household wealth index as well as capacity-to-pay values from the WHO World Health Survey, which confirms the robustness of our measure of capacity-to-pay, (see appendix).

As discussed in Khatib et al. (2016) we assume participants purchase their medicines from pharmacies rather than non-pharmacy retailers. Furthermore, we assume households pay the full cost of the medicines, that is, the costs of the medicines are not partially or fully subsidized by governments or other third-parties (e.g. health insurance).

Statistical Analysis

We estimated the association between availability, affordability and use of BP lowering medicines and BP control in separate models for participants with known hypertension (N=33,045). We used multilevel, mixed-effects logistic regression models, accounting for clustering at the community level, (details on the methods and full set of results can be found in the appendix). All statistical models were adjusted for the potential confounders: age, sex, education level, years since hypertension diagnosis, and urban versus rural geographic location. A summary of means and proportions of the adjusted variables for the hypertension population is available in Table 4.2. For the affordability analysis, we excluded households that did not report income or food expenditure information, as the absence of this information precluded us from estimating capacity-to-pay (N= 13,589 households). Individuals in households that reported household income and food expenditure were similar to those that did not (appendix). Moreover, imputing the mean value within each community for those with missing information on household income and food expenditure did not alter the associations. Adjusted and unadjusted associations between availability, affordability and medicine use and BP control were reported as odds ratios (OR) with 95% confidence intervals. Stata (version 14) was used for all statistical analyses.

Results

Availability of blood pressure lowering medicines

About 90% of communities had at least one BP lowering medicine available in the local pharmacy surveyed (564 out of 626 communities), with few communities (62 out of 626) not having any BP lowering medicines available (Figure 4.1). These communities were predominantly located in low and low-middle income countries. Most communities in high-income countries (94%) and India (74%) had all four drug classes available. Availability of all four BP lowering drug classes was lowest in low-income countries (13%), excluding India. Urban and rural differences in the availability of BP lowering drugs were also observed; these differences were most marked in low-middle income and low-income countries. For example, 57% of urban communities in low-middle income countries carried at least 4 BP lowering drug classes, compared to 37% of rural communities (appendix).

The most common drug class also varied across regions; ß-blockers (87%) and calcium-channel blockers (83%) were the most commonly available drug classes in upper-middle income and low-income countries. Whereas in low-middle income countries ACE-inhibitors (80%) followed by ß-blockers (69%) were the most commonly available drugs (appendix).

Costs and affordability of blood pressure lowering medicines

In each group of countries, categorized according to economic development, diuretics were the least expensive class followed by ß-blockers. Table 4.1 lists the median monthly cost of one, two, and three BP lowering medicines (using the monthly cost of the lowest cost, lowest two, and lowest three medicines in each community), median household capacity-to-pay, and the median monthly costs of BP lowering medicines, metformin, and the lowest cost statin either alone or in various combinations.

Median monthly capacity-to-pay was highest in high-income countries (US$2,545, IQR (US$1617, US$3,585)) and lowest in low-income countries (US$52, IQR (US$21, US$104 i.e. a 48-fold difference). Household capacity-to-pay was lower in rural communities across all country groups, with significant differences in upper-middle income and low-income countries, including India (upper-middle income: urban= US$416 and rural= US$183; low-income: urban= US$78, rural= US$32; India: urban= US$167 and rural= US$26, see appendix).

The monthly cost of the lowest cost one, two, and three BP lowering medicines were highest in absolute terms in high-income countries but, given the much higher incomes in high-income countries, it constituted a lower proportion of household capacity-to-pay (<1% in high-income compared to 1%- 11% in low-income countries for 1-3 BP lowering medicines, respectively). The monthly costs of the lowest cost BP lowering medicines in upper-middle income countries were similar to high-income countries, however, they accounted for a larger fraction of household capacity-to-pay in the former (i.e. 4%, and 7% for two and three lowest cost BP lowering medicines, respectively). This observation is largely driven by differences in household capacity-to-pay between high-income and upper-middle income countries; median capacity-to-pay in high-income communities was approximately 7 times that in upper-middle income countries. The difference in capacity-to-pay between high-income and upper-middle income communities were further exacerbated once we took into account household expenditure on housing and transportation in the sensitivity analysis (e.g. median capacity-to-pay of US$2056 in high-income countries compared to US$171 in upper-middle income countries, approximately 11-fold difference).

Communities in low-middle income countries had some of the lowest monthly costs for BP lowering medicines, Table 4.1. However, when the monthly cost of metformin or the lowest cost statin is added to the cost of two lowest cost BP lowering medicines, the median monthly costs increased considerably in low-middle income (~US$4 increase when metformin is added, ~US$8 increase when a statin is added, ~US$8 increase when both are added) and low-income countries (~ US$4 increase with added metformin, ~US$22 increase with added statin or when both are added).

Few households in high-income countries were unable to afford the lowest cost BP lowering medicines (<1% or n= 44 households out of 10,880 were unable to afford the two lowest cost BP lowering medicines, Figure 4.2), even after taking into account the costs of housing and transportation (sensitivity analysis discussed below). The proportion of households unable to afford the lowest cost BP lowering medicines was highest in low-income countries, including India, which had the highest proportion of households unable to afford hypertension medicines (low-income: 31%, n=1069 out of 3,479 households; India 36%, n=6,139 out of 16,955 households unable to afford the two lowest cost BP lowering medicines). Adding the cost of metformin or the lowest cost statin to the monthly cost of the two lowest cost BP lowering medicines increased the proportion of households unable to afford the medicines, but the increase was most marked in low-middle income and low-income countries. For example, in low-income countries 31% of households were unable to afford the monthly cost of the two lowest cost BP lowering medicines. Adding metformin increased the proportion to 39% (n=1366 out of 3,479 households); adding the lowest cost statin increased the proportion to 75% (n=2277 out of 3,479), and including both metformin and the lowest cost statin increased the proportion to 80% of households (n=2441 out of 3,479). In contrast, almost all households in high-income countries were able to afford the cost of the two lowest cost BP lowering medicines and metformin (99%,), the two lowest cost BP lowering medicines and the lowest cost statin (98%), or all drugs (97%).

In a sensitivity analysis, we revise our estimates of household capacity-to-pay by excluding monthly household expenditure on housing and transportation in addition to expenditures on food, from monthly household income in a subset of PURE participants for whom the data is available (N= 23, 888), see appendix. The proportion of households unable to afford the lowest cost BP lowering medicines increased in all countries, categorized according to economic development, however the pattern remains similar to the main analysis.

Influence of availability and affordability in relation to use of medicines

Our subsequent analysis is restricted to the subset of participants with known hypertension (n=33,045). Of those with known hypertension, 59% used at least one BP lowering medicine (n=19,481); 26% used ACE inhibitors or angiotensin-II receptor blockers (n=8,697), 19% used diuretics (n=6,221), 15% used ß-blockers (n=5,028), and 16% used calcium-channel blockers (n=5,146). Use of combination therapy was relatively low, with only 24% (n=7,879) taking more than one BP lowering medicine (19% taking 2, 5% taking 3 and 0·64% taking 4).

Participants with known hypertension living in communities that have all four BP lowering drug classes available were more likely to use at least one BP lowering medicine (OR=2·23, p<0·001, 95% CI (1·59, 3·12)), use combination therapy (OR=1·53, p<0·01, 95% CI (1·13, 2·07)) or have their BP controlled (OR= 2·06, p<0·001, 95% CI (1·69, 2·50)), relative to the reference category of living in a community where BP lowering medicines were not available, Figure 4.3. Similarly, participants with known hypertension and able to afford up to four BP lowering medicines were more likely to use at least one BP lowering medicine (OR= 1·42, p<0·001 95% CI (1·25, 1·62)), use combination therapy (OR=1·26, p<0·01, 95% CI (1·08, 1·47)) or have their blood pressure controlled (OR=1·13, 95% CI (1·00, 1·28)) relative to the reference category of not being able to afford blood-pressure lowering medicines.

Discussion

Although BP lowering medicines are listed as WHO essential medicines, their access remains a global concern. While at least one BP lowering medicine was available in 90% of the pharmacies surveyed, the availability of two or more classes of drug therapy was lower in low and low-middle income countries relative to high-income countries (and India). Our findings with respect to affordability parallel the patterns observed for availability, with one important exception- even though BP lowering medicines were widely available in India, they were potentially unaffordable to many households due to low capacity-to-pay and higher medicine prices compared to other low-income countries. Among participants aware of their hypertension diagnosis, we find strong positive associations between availability and affordability of BP lowering medicines and use of BP lowering medicines (including combination therapy), and BP control. Our results indicate that multiple BP lowering drug classes need to be available and affordable to improve hypertension control. This may reflect the needs of different patients or the preferences of different physicians for prescribing specific BP lowering drugs. Physicians may prefer to prescribe different classes of BP lowering drugs to patients under the assumption that patients differ in their response and tolerance to different medicines.

Previous studies have shown that hypertension treatment practices (e.g. blood pressure threshold for initiating drug therapy, or use of specific drugs) vary by patient characteristics, their risk and by region and these may change over time (Jarari et al., 2015). Our estimates for affordability and use of BP lowering medicines and BP control are consistent with studies showing that adherence to medicines declines as out of-pocket expenditure increases, whereas improvements in insurance coverage for medicine costs and low out of-pocket expenditure improves adherence (Doshi et al., 2009; Viswanathan et al., 2012). These results demonstrate the importance of developing policies that seek to make multiple drug classes available and affordable, particularly in low and middle-income countries.

We estimate that the median monthly retail cost of the two lowest cost BP lowering medicines is approximately US$4·95. This varies from US$0·33 in low-middle income countries (where they are subsidized by governments, for example, in the occupied Palestinian Territory and by the government in Iran (Dinarvand, 2009)) to $US16·68 in high-income countries. Previous studies have reported costs for a multidrug regimen targeting hypertension and cardiovascular disease (Lim et al., 2007), and costs for delivering a hypertension management program that includes at least one BP lowering medicine (World Health Organization, 2011). However, our medicine prices are gathered directly from the community retail pharmacies in which the PURE participants live and therefore represent prices members of that community would actually face, which include mark-ups along the supply chain. In contrast, medicine prices used in the costing exercises conducted for the multidrug regimen (Lim et al., 2007) and hypertension management program (World Health Organization, 2011) use median procurement prices obtained from the International Reference Price Index created by Management Sciences for Health for a select number of developing countries (Attaei and Yusuf, 2017). Previous studies have shown marked differences between prices charged to patients and procurement prices (Cameron et al., 2009). Further, while organisations such as Health Action International have undertaken extensive studies on availability and pricing of medicines in many countries (Cameron et al., 2009; Mendis et al., 2007; van Mourik et al., 2010), our study is, to our knowledge, the first attempt to link such data to use of BP lowering drugs in countries at a range of economic levels.

Improving hypertension control at a population level will require strategies beyond improving access to low cost BP lowering medicines (Khatib et al., 2014). For example, although costs attributed to accessing the health care system are important barriers in low and low-middle income countries, additional barriers imposed by providers, the broader health systems in which they work (e.g. access to a qualified health provider) and patient characteristics (e.g. health literacy) are important factors for achieving blood pressure control (Khatib et al., 2014). In high-income countries, the influence of availability and affordability was minimal, indicating that other factors are important for blood pressure control in these countries. Further research into contextual and cultural barriers, factors associated with the health care system, and personal preferences have been conducted, with additional studies underway in PURE (Legido-Quigley et al., 2015; Risso-Gill et al., 2015). These studies will help develop a comprehensive approach to improve hypertension control globally from the current levels where only 13% of hypertensives have controlled blood pressure. However, based on our data, improving access to affordable blood pressure lowering medicines in low and low-middle income countries will likely substantially improve rates of hypertension control in these countries.

Limitations

In estimating affordability, we assume that households pay the full retail price. We therefore do not take into account the role of insurance or any other form of reimbursement individuals or households may receive. However, previous studies have indicated that the majority of pharmaceutical expenditure in low and low-middle income countries occurs in the private sector, often in the form of out-of-pocket expenditure (Wirtz et al., 2016). Some patients may prioritize other expenses over the treatment of their hypertension, our measure of affordability does not take into account participant prioritization or preferences. If medicines are more readily available in non-pharmacy vendors or in pharmacies not surveyed in our study, our estimates of availability are underestimates of true availability.

The methods we use to define hypertension and blood pressure control are standard in large epidemiologic studies. While multiple blood pressure measurements on three to five occasions would provide greater precision, this is not feasible in large multi-country studies involving over a hundred thousand participants, and moreover, is rarely done in routine clinical practice in most settings, especially in low-middle income countries.

Of the new drug classes for BP lowering, angiotensin II receptor blockers (ARBs) are used with some frequency especially when ACE inhibitors are not tolerated. However, ARBs are more expensive than ACE inhibitors and so our estimates on affordability is unlikely to change. Furthermore, because we use cross-sectional observational data, we cannot demonstrate that the associations between availability, affordability and medicine use and BP control are causal.

Conclusions

Our results are directly relevant to public policies that are targeted at reducing the global burden of CVD by improving access to essential medicines, particularly the stated goals of a 25% reduction in premature CVD deaths by 2025 and the even more ambitious targets in the Sustainable Development Goals (United Nations, 2015). Until key lifesaving medicines are available and affordable to most populations, hypertension control is likely to be suboptimal especially in low and low-middle income countries. Similar conclusions can be drawn from the report by Khatib et al. 2016 with regards to improving use of proven medicines for secondary prevention (Khatib et al., 2016). In the context of hypertension control, many patients also have diabetes, CVD or other indications for statins. Such patients are at high risk and will benefit from combination therapy, which could include two blood pressure lowering drugs, a statin and/or metformin (Yusuf et al., 2016a, 2016b). However, these drug therapy combinations are unaffordable for most people in low and low-middle income countries. For example, a combination therapy that includes the two lowest cost blood pressure lowering medicines, the lowest cost statin, and metformin is unaffordable for 80% of households in low-income countries. Therefore, improving the outcomes of individuals with hypertension and reducing CVD requires a broader strategy that includes making other essential medicines, such as statins or glucose lowering medicines, widely accessible and affordable.

Panel: research in context

Evidence before this study

We searched the PubMed database for articles on the availability and affordability of blood pressure lowering medicines in countries at various stages of economic development, without any language or date restrictions. Our search terms included "availability", "affordability", "blood pressure lowering drugs or medicines", and "antihypertensive". We excluded studies that did not include a measure of affordability for the medicines.

We identified four studies that assessed the availability and affordability of different medicines, including blood pressure lowering medicines. Only two studies provided a description of the availability of blood pressure lowering medicines; one for six low and middle-income countries and the other in 36 high-, middle-, and low-income countries. Both studies estimated affordability using the number of days' wages needed to pay the lowest paid unskilled government worker to purchase one-month supply of the medicines. This approach to estimating affordability does not allow for inter-household comparisons. Neither study assessed the association between availability, affordability and use of blood pressure lowering medicines or blood pressure control.

Added value of this study

Our study is the first to describe the availability and affordability of commonly used blood pressure lowering medicines, as well as combination therapy using multiple therapies (e.g. antidiabetic and a statin) in high-, upper middle-, lower middle- and low-income countries. It is also the first to relate availability and affordability of blood pressure lowering medicines to use of blood pressure lowering medicines and blood pressure control.

We find that a large proportion of communities in low and middle-income countries do not have access to multiple blood pressure lowering medicines, and when available, they are often not affordable. Our results indicate that multiple blood pressure lowering drug classes need to be available and affordable to improve hypertension control.

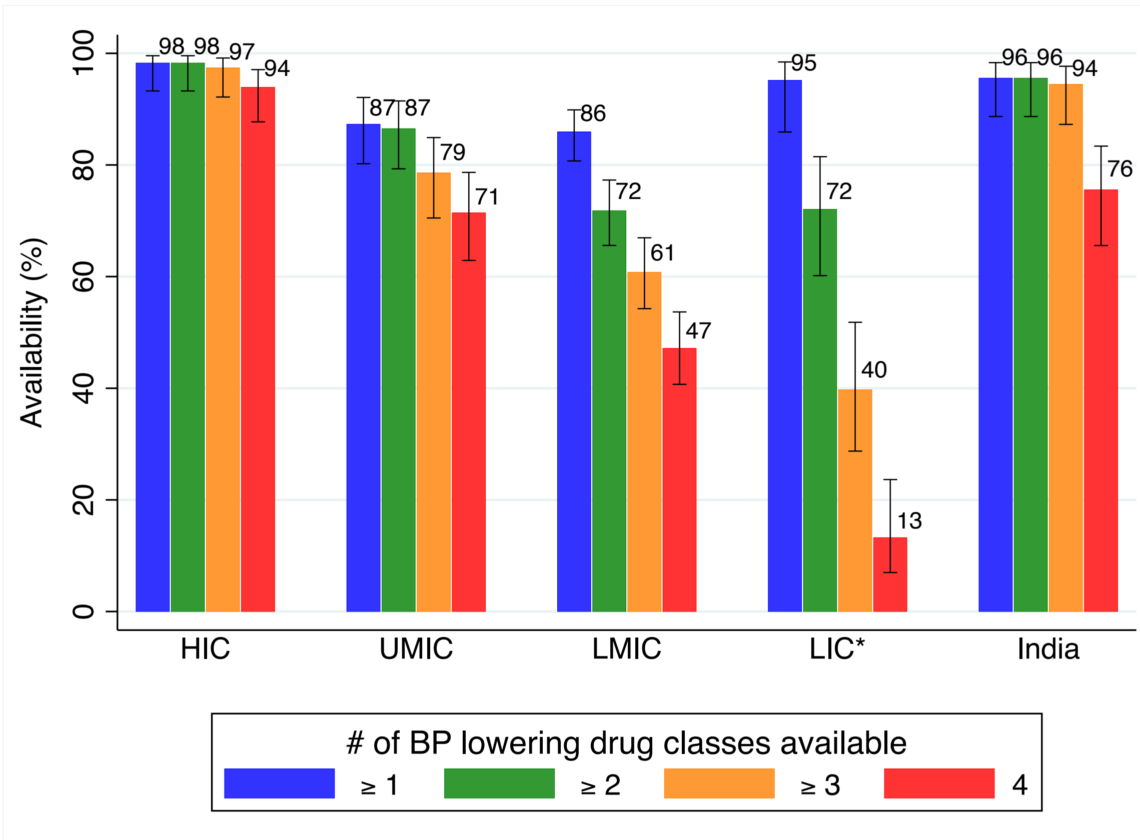
Implications of all the available evidence

Improving the availability and affordability of blood pressure lowering medicines are essential for improving control of hypertension, particularly in low and middle-income countries where 80% of the CVD burden exists. Our results are therefore directly relevant to public policies that are targeted at reducing the global burden of CVD, particularly the stated goals of a 25% reduction in premature CVD deaths by 2025 and the even more ambitious targets in the Sustainable Development Goals.

However, improving hypertension control at a population level will also require strategies beyond improving access to low cost blood pressure lowering medicines. Further research is warranted into contextual and cultural barriers, factors associated with the health care system, and personal preferences.

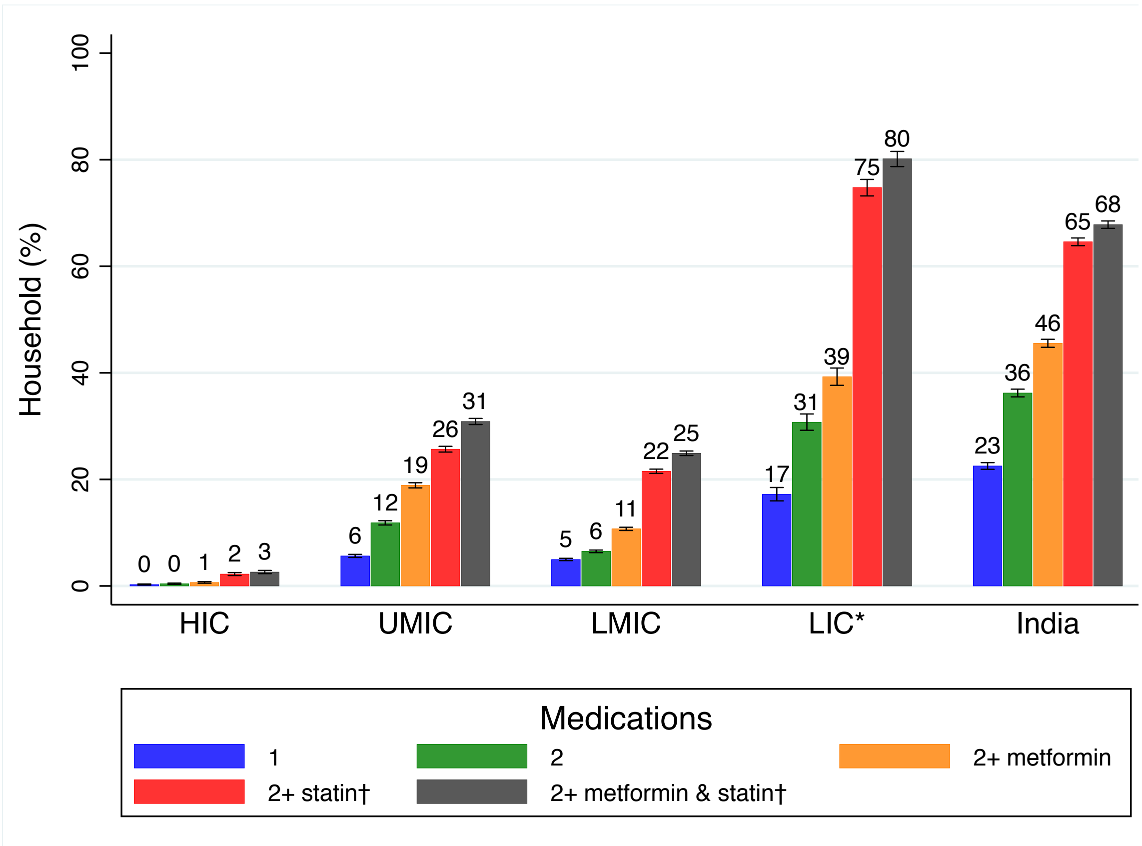
Tables and Figures:

Figure 4.1 Availability of one, two, three, and four classes of blood pressure lowering medicines in 626 PURE communities.



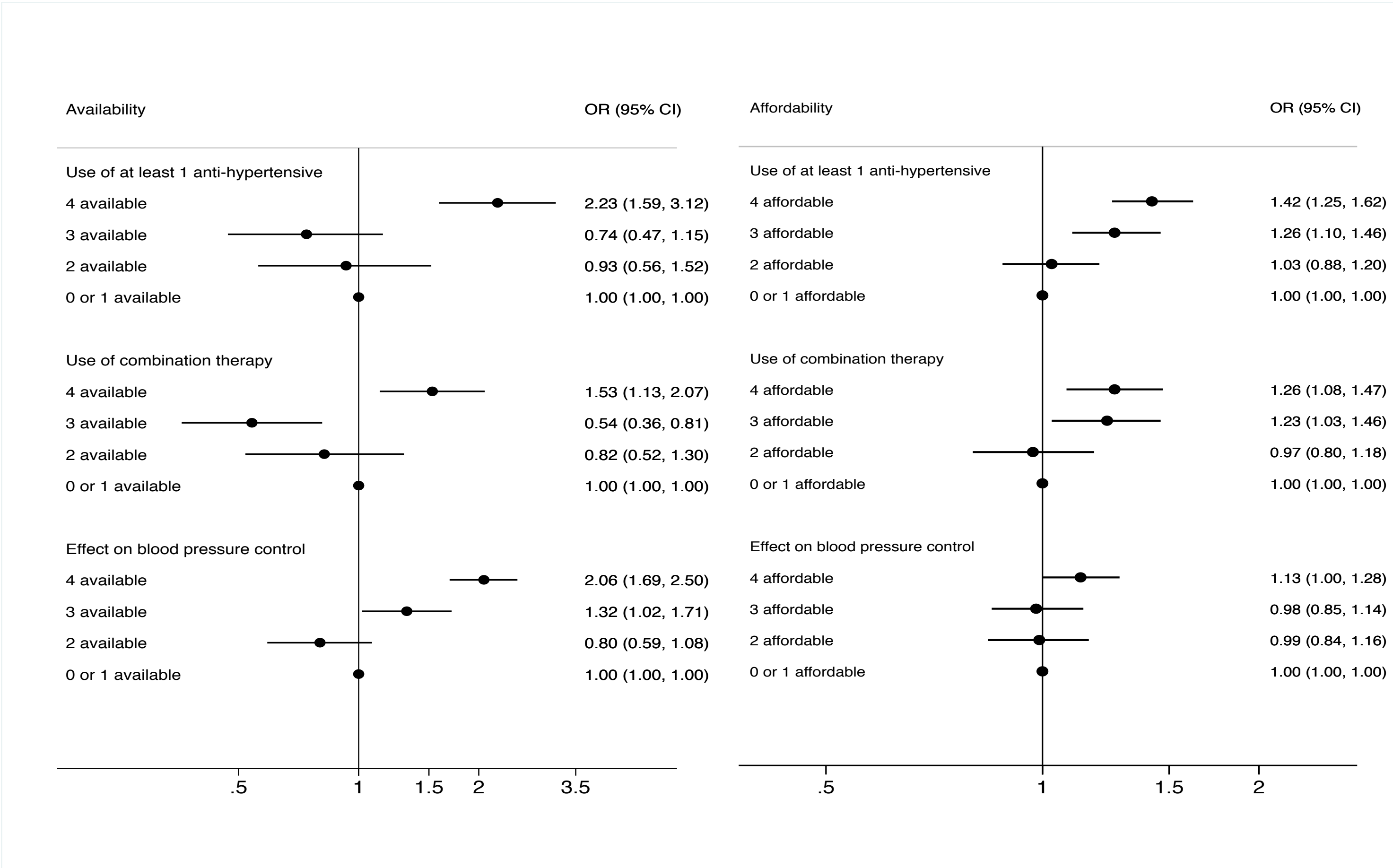
HIC= high income countries; UMIC=upper middle income countries; LMIC=lower middle income countries; LIC*= low income countries excluding India

Figure 4.2 Proportion of households that cannot afford one, two, two BP lowering medicines and metformin, two BP lowering medicines and a statin, and two BP lowering medicines, metformin, and a statin§ using a 20% of capacity-to-pay threshold, N = 98,785 households



HIC= high income countries; UMIC=upper middle income countries; LMIC=lower middle income countries; LIC*= low income countries excluding India & Zimbabwe † Tanzania excluded because statins are unavailable. BP= blood pressure
§In calculating affordability we use the cost of the lowest cost medicine(s)

Figure 4.3 Associations between availability and affordability§ and use of at least one blood pressure lowering medicine, use of combination therapy, and blood pressure control in participants with known hypertension



Adjusted for: age, sex, education, years since hypertension diagnosis, urban versus rural location; clustered at the community level
Affordability analysis restricted to participants living in communities where at least 1 blood pressure lowering medicine is available
§ In calculating affordability we use the cost of the lowest cost medicine(s)

Table 4.1 Monthly household capacity-to-pay (2010 US dollars), and monthly costs (2010 US dollars) of blood-pressure lowering(s) medicines

	No. of Comm-unities	No. of House-holds	Median capacity-to-pay (IQR)	Median capacity-to-pay (housing and transportation costs incorporated) (IQR)[a]	Monthly Cost of the lowest cost anti-hyp. medicine	Monthly Cost of the 2 lowest cost anti-hyp. medicines	Monthly Cost of the 2 lowest cost anti-hyp. + metformin	Monthly Cost of the 2 lowest cost anti-hyp. + lowest cost statin†	Monthly Cost of the 2 lowest cost anti-hyp. + metformin & lost cost statin†	Monthly Cost of the 3 lowest cost anti-hyp. medicines †
HIC	**90**	**10,880**	**2545 (1617, 3585)**	**2056 (1195, 2976)**	**4 (2, 9)**	**17 (3, 25)**	**26 (7, 35)**	**44 (5, 70)**	**52 (9, 84)**	**33 (6, 49)**
UMIC	**125**	**25,235**	**290 (115, 671)**	**171 (49, 365)**	**4 (2, 6)**	**12 (8, 14)**	**18 (11, 20)**	**21 (18, 35)**	**27 (23, 43)**	**22 (20, 24)**
LMIC	**225**	**40,236**	**173 (75, 338)**	**137 (45, 277)**	**0·09 (0·09, 0·9)**	**0·33 (0·2, 3)**	**4 (0·5, 10)**	**8 (3, 18)**	**8 (5, 24)**	**1 (0·4, 8)**
LIC*	**68**	**3,782**	**52 (21,104)**	**22 (0·2, 63)**	**0·7 (0·7, 1)**	**2 (2, 2)**	**6 (4, 7)**	**24 (20, 24)**	**24 (24, 28)**	**6 (5, 6)**
India	**89**	**16,955**	**61 (18, 218)**	**41 (0, 155)**	**3 (2, 4)**	**9 (6, 10)**	**12 (10, 13)**	**30 (24, 38)**	**33 (27, 42)**	**15 (12, 16)**
Overall	**597**	**97,088**	**204 (70, 535)**	**169 (42, 462)**	**2 (0·4, 4)**	**5 (2, 11)**	**10 (4, 18)**	**21 (8, 33)**	**26 (9, 39)**	**11 (4, 22)**

Notes: abbreviations: HIC = high-income country; UMIC = upper-middle-income country; LMIC= low-middle-income country LIC = low-income country. Categorization of economic level for each Country based on the 2006 information from the World Bank. Costs are median (IQR), medicines include ACE-inhibitors, ß- blockers, calcium-channel blocker, and diuretics*Capacity-to-pay and medicine costs exclude India, medicine costs also exclude Zimbabwe because purchasing power parity values were unavailable † Tanzania excluded because only two classes of blood-pressure lowering medicines are available and statins are unavailable in the communities studied, resulting in 588 communities. [a]Capacity-to-pay estimates based on a subset of PURE participants (N=23,888) with information on housing and transportation costs which were incorporated into capacity-to-pay calculation
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Table 4.2 Baseline characteristics of participants aware of their hypertension diagnosis, N = 33,045

	High-Income Countries		Upper-Middle Income Countries		Low- Middle Income Countries		Low- Income Countries	
	Men N = 1809	Women N = 1828	Men N = 4297	Women N = 7567	Men N = 4691	Women N = 7143	Men N = 2175	Women N = 3535
Age – yr[1]	58 ± 8.3	57 ± 8.1	57 ±8.8	56 ±8.9	56 ±9.3	56 ±8.6	55 ±9.7	53 ±9.9
Education level - no(%)								
Low[2]	277 (15)	448 (24.5)	2273 (52.9)	4801 (63.5)	1558 (33.2)	3864 (54.1)	481 (22.1)	1839 (52.0)
Secondary	537 (29.7)	591 (32.3)	1252 (29.1)	1983 (26.2)	2084 (44.4)	2525 (35.4)	1008 (46.3)	1339 (37.9)
University	991 (54.8)	789 (43.2)	767 (17.9)	776 (10.3)	1040 (22.2)	741 (10.4)	681 (31.3)	342 (9.7)
Years since hypertension diagnosis								
1 year to 5 years	665 (36.8)	602 (32.9)	1726 (40.2)	2920 (38.6)	1784 (38.0)	2690 (37.7)	935 (43.0)	1470 (41.6)
>5 years	905 (50.0)	956 (52.3)	1937 (45.1)	3689 (48.8)	2191 (46.7)	3451 (48.3)	764 (35.1)	1307 (37.0)
Living in a rural community	514 (28.4)	539 (29.5)	1922 (44.7)	3397 (44.9)	2064 (44.0)	3040 (42.6)	718 (33.0)	1444 (40.9)
Proportion with blood pressure controlled[3]	633 (35.0)	697 (38.1)	829 (19.3)	2017 (26.7)	886 (18.9)	1562 (21.9)	548 (25.2)	766 (21.7)
Proportion with a diagnosis of cardiovascular disease[4]	341 (18.9)	182 (10.0)	568 (13.2)	657 (8.7)	1031 (22.0)	1196 (16.7)	259 (11.9)	258 (7.3)
Proportion with a diagnosis of diabetes[5]	512 (28.3)	448 (24.5)	1170 (27.2)	1927 (25.5)	974 (20.8)	1384 (19.4)	736 (33.8)	986 (27.9)

[1] Plus-minus values are means ±SD
[2] Low educational level defined as no education, primary education only or unknown educational level
[3] Blood pressure controlled defined as systolic and diastolic blood pressures less than 140/90 mm Hg
[4] Cardiovascular disease defined as an individual with previous stroke or coronary artery disease (e.g. myocardial infarction, coronary artery bypass graft surgery, percutaneous coronary angioplasty, or angina)
[5] Defined as self-reported or fasting glycemia ≥ 7mmol/L

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Web appendix material:

Appendix 4.1 PURE study participant selection methodology as excerpted from Teo et al.

Selection of Countries

The choice and number of countries selected in PURE reflects a balance between involving a large number of communities in countries at different economic levels, with substantial heterogeneity in social and economic circumstances and policies, and the feasibility of centers to successfully achieve long-term follow-up (see appendix 4.2 table 1). Thus, PURE included sites in which investigators are committed to collecting good-quality data for a low-budget study over the planned 10-year follow-up period and did not aim for a strict proportionate sampling of the entire world.

Selection of Communities

Within each country, urban and rural communities were selected based on broad guidelines (see appendix 4.1 table 1). A common definition for "community" that is applicable globally is difficult to establish.[2] In PURE, a community was defined as a group of people who have common characteristics and reside in a defined geographic area. A city or large town was not usually considered to be a single community, rather communities from low-, middle-, and high-income areas were selected from sections of the city and the community area defined according to a geographical measure (eg, a set of contiguous postal code areas or a group of streets or a village). The primary sampling unit for rural areas in many countries was the village. The reason for inclusion of both urban and rural communities is that for many countries, urban and rural environments exhibit distinct characteristics in social and physical environment, and hence, by sampling both, we ensured considerable variation in societal factors across PURE communities.

The number of communities selected in each country varied, with the aim to recruit communities with substantial heterogeneity in social and economic circumstances balanced against the capacity of local investigators to maintain follow-up. In some countries (eg, India, China, Canada, and Colombia), communities from several states/provinces were included to capture regional diversity, in policy, socioeconomic status, culture, and physical environment. In other countries (eg, Iran, Poland, Sweden, and Zimbabwe), fewer communities were selected.

Selections of Households and Individuals

Within each community, sampling was designed to achieve a broadly representative sample of that community of adults aged between 35 and 70 years (see appendix 4.1 table 1). The choice of sampling frame within each center was based on both "representativeness" and feasibility of long-term follow-up, following broad study guidelines. Once a community was identified, where possible, common and standardized approaches were applied to the enumeration of households, identification of individuals, recruitment procedures, and data collection.

The method of approaching households differed between regions. For example, in rural areas of India and China, a community announcement was made to the village through contact of a community leader, followed by in-person door-to-door visits of all households. In contrast in Canada, initial contact was by mail followed by telephone inviting members of the households to a central clinic. Households were eligible if at least 1 member of the household was between the ages of 35 and 70 years and the household members intended to continue living in their current home for a further 4 years.

For each approach, at least 3 attempts at contact were made. All individuals within these households between 35 and 70 years providing written informed consent were enrolled. When an eligible household or eligible individual in a household refused to participate, demographics and self-reported data about CVD risk factors, education, and history of CVD, cancers and deaths in the households within the two previous years were recorded.

To ensure standardization and high data quality, we used a comprehensive operations manual, training workshops, DVDs, regular communication with study personnel and standardized report forms. We entered all data in a customized database programmed with range and consistency checks which was transmitted electronically to the Population Health Research Institute in Hamilton (Ontario, Canada) where further quality checks were implemented.

Table 1: Guidelines for selection of Countries, Communities, Households, and Individuals recruited to PURE
Countries
1. High-income countries, middle-income countries, and low-income countries, with the bulk of the recruitment from low- and middle-income regions.
2. Committed local investigators with experience in recruiting for population studies.

Communities
1. Select both urban and rural communities. Use the national definition of the country to determine urban and rural communities.
2. Select rural communities that are isolated (distance of >50 km or lack easy access to commuter transportation) from urban centers. However, consider ability to process bloods samples, eg, villages in rural developing countries should be within 45-min drive of an appropriate facility.
3. Define community to a geographical area, eg, using postal codes, catchment area of health service/clinics, census tracts, areas bordered by specific streets or natural borders such as a river bank.
4. Consider feasibility for long-term follow-up, eg, for urban communities, choose sites that have a stable population such as residential colonies related to specific work sites in developing countries. In rural areas, choose villages that have a stable population. Villages at greater distance from urban centers are less susceptible to large migration to urban centers.
5. Enlist a community organization to facilitate contact with the community, eg, in urban areas, large employers (government and private), insurance companies, clubs, religious organizations, clinic or hospital service regions. In rural areas, local authorities such as priests or community elders, hospital or clinic, village leader, or local politician.
Individual
1. Broadly representative sampling of adults 35 to 70 years within each community unit.
2. Consider feasibility for long-term follow-up when formulating community sampling framework, eg, small percentage random samples of large communities may be more difficult to follow-up because they are dispersed by distance. In rural areas of developing countries that are not connected by telephone, it may be better to sample entire community (ie, door-to-door systematic sampling).
3. The method of approach of households/individuals may differ between sites. In MIC and HIC, mail, followed up by phone contact may be the practical first means of contact. In LIC, direct household contact through household visits may be the most appropriate means of first contact.
4. Once recruited, all individuals are invited to a study clinic to complete standardized questionnaires and have a standardized set of measurements.

Appendix 4.2 Validation of capacity-to-pay values as excerpted from Khatib et al.

The health economics literature recommends using total household expenditures to estimate capacity-to-pay rather than asking about the total household income earned, as the latter might be under or over reported.[3] Self-employed participants may under report their total income earned, especially in rural and low income countries where self-employment is common. Participants may also choose to conceal other sources of income such as government subsidies and other non-monetary income sources. On the other hand, some households may report higher earnings during an interview in order to seem more socially acceptable.

The PURE study collected data on household income earned rather than household expenditures. This was done because of the complexity of recording household expenditures accurately in such a large study. Therefore, we compare capacity-to-pay values derived from the PURE study with values from the World Health Survey (WHS) which collected this information by asking about total household expenditures for nine of the 18 PURE countries.[4] Additionally, we assess the face validity of the capacity-to-pay values derived from the PURE study by ranking them with per capita Gross National Product (GNI) and quintiles of the household wealth index. We also compare the characteristics of study participants between households that reported the information needed to calculate capacity-to-pay and those that did not report this information.

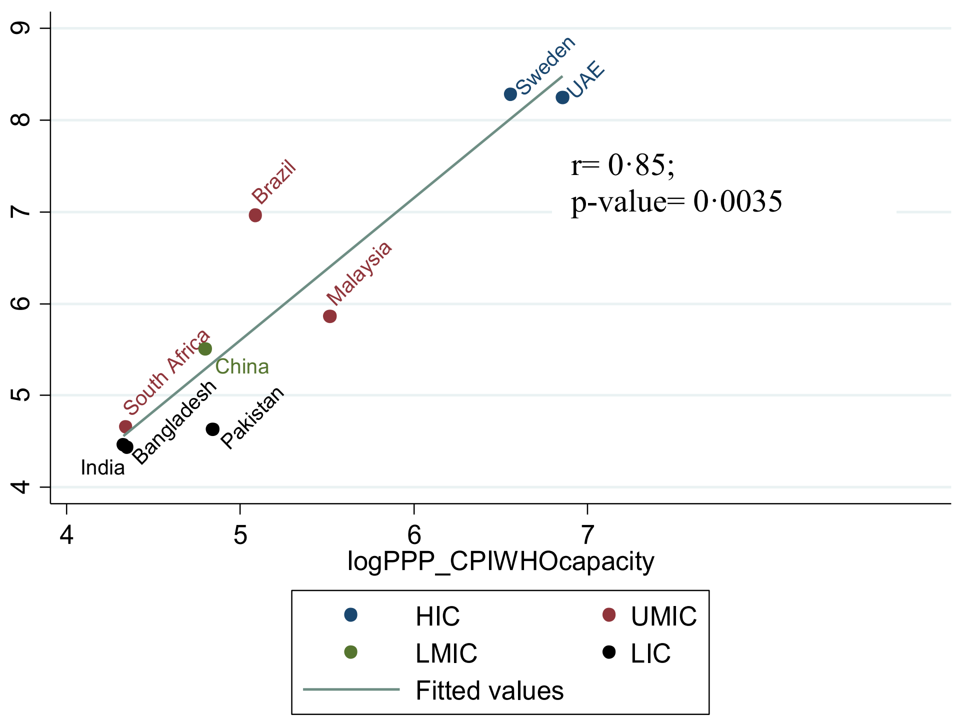
Capacity-to-pay values collected from the PURE study were compared to those from WHS, which was developed by the World Health Organization (WHO). The data were compared in nine of the 18 PURE countries for which WHS data were available: Sweden, UAE, Brazil, Malaysia, South Africa, China, India, Pakistan, and Bangladesh. Standardized WHS questionnaires were used to collect total monthly household expenditure and total monthly expenditures on food from households representing each country.[4]We calculated the median capacity-to-pay from the WHS data for these countries by subtracting expenditures on food from total household expenditures.

Data for the PURE study were collected between 2003 and 2010; the WHS the data were collected in 2003. Both studies collected data in the local currency for each country. Capacity-to-pay values for both studies were adjusted for inflation to 2010 values using consumer price index (CPI) values. CPI reflects the change in price levels of a market basket of consumer goods and services purchased by households.[5] For secondary analyses values were also converted to US dollars that are adjusted for purchasing power parity (PPP) from 2010. PPP is defined as the number of units of a country's currency required to buy the same amounts of goods and services in the domestic market as $1 USD would buy in the United States.[6] Zimbabwe is excluded from these analyses because CPI and PPP values were not available for the country during the period of data collection. To remove outliers (either implausible or extreme values) income and expenditures on food were set at the 5th and 95th percentiles. If the reported expenditure on food was more than the total reported household income, capacity-to-pay values were set to zero.

Median capacity-to-pay values were calculated for each country and compared across values obtained from PURE and WHS. To assess face validity, the median capacity-to-pay values from PURE were ranked by GNI. One would expect that, countries with a higher GNI would have a higher median capacity-to-pay. Similarly, the median capacity-to-pay values were ranked by quintiles of household wealth index, stratified by country income group. Household wealth was calculated based on a checklist of amenities which included: electricity, car, computer, television, motorbike, livestock, fridge, other four-wheel vehicles, washing machine, stereo, bicycle, kitchen processor, telephone, kitchen window, and land ownership. A binary classification of 'yes' or 'no' was created for each item for each household and then a principal components analysis was used to assign the scores.[7] In this appendix, India was grouped with other LIC. Correlation and rank order were assessed using Spearman rank correlations (rho). A correlation coefficient (Spearman rho) of 0·70 is the standard for demonstrating a good correlation.

Correlation between capacity-to-pay values obtained from the PURE study and from WHO

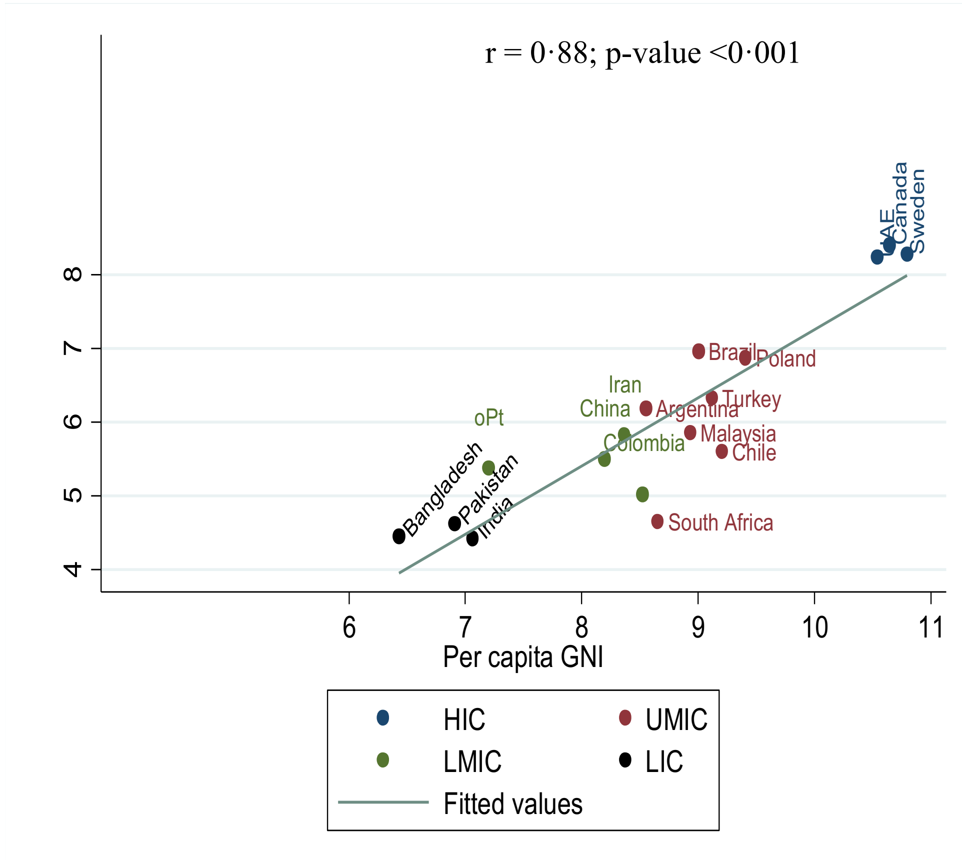
Figure 1 Country median capacity-to-pay- correlation between data obtained from PURE and from WHO, n=9 countries



- Data from WHO was available for 9 of the 18 PURE countries
- WHO data were obtained from the World Health Survey (WHS)
- Capacity-to-pay values are presented on a logarithmic scale
- HIC=high income countries; UMIC= upper middle income countries; LMIC= lower middle income countries; LIC= low income countries
- r= Spearman rho correlation

Rank of median country capacity-to-pay by per capita GNI

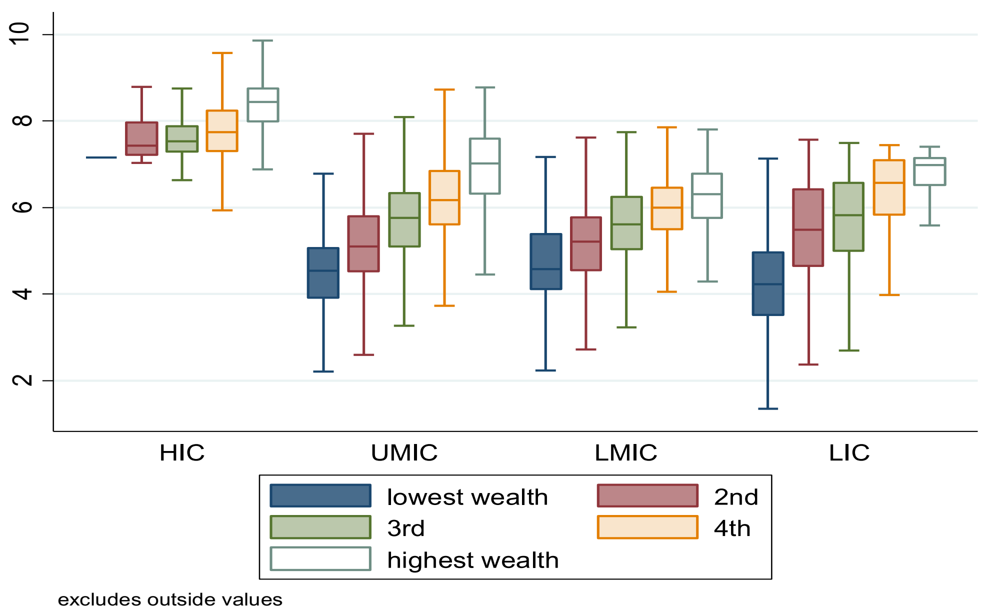
Figure 2: County median capacity-to-pay in relation to per capita GNI in USD, PPP adjusted, n=17 countries



- Capacity-to-pay and per capita GNI values are presented on a logarithmic scale.
- HIC=high income countries; UMIC= upper middle income countries; LMIC= lower middle income countries; LIC= low income countries; PPP= purchasing power parity; r= Spearman rho correlation.
- PPP values for Zimbabwe were not available

Median household capacity-to-pay by quintiles of household wealth index

Figure 3: Household capacity-to-pay at different levels of household wealth stratified by country income group in USD (PPP adjusted), n=94,919households



- Capacity-to-pay is presented on a logarithmic scale
- Box plots present the median values, upper and lower interquartile ranges, and minimum and maximum values for each location.
- HIC=high income countries; UMIC= upper middle income countries; LMIC= lower middle income countries; LIC= low income countries; PPP= purchasing power parity

Appendix 4.3 Incorporating household expenditure on housing and transportation into capacity-to-pay values

During the current cycle of follow-up, we are collecting additional data from all countries to better understand household consumption and expenditure behaviour. This includes data on expenditures related to housing (e.g. rent or mortgage and utilities such as electricity, water, cooking/heating fuel, telephone, internet, cable tv) and transportation (e.g. public transit fares, fuel for personal vehicle).

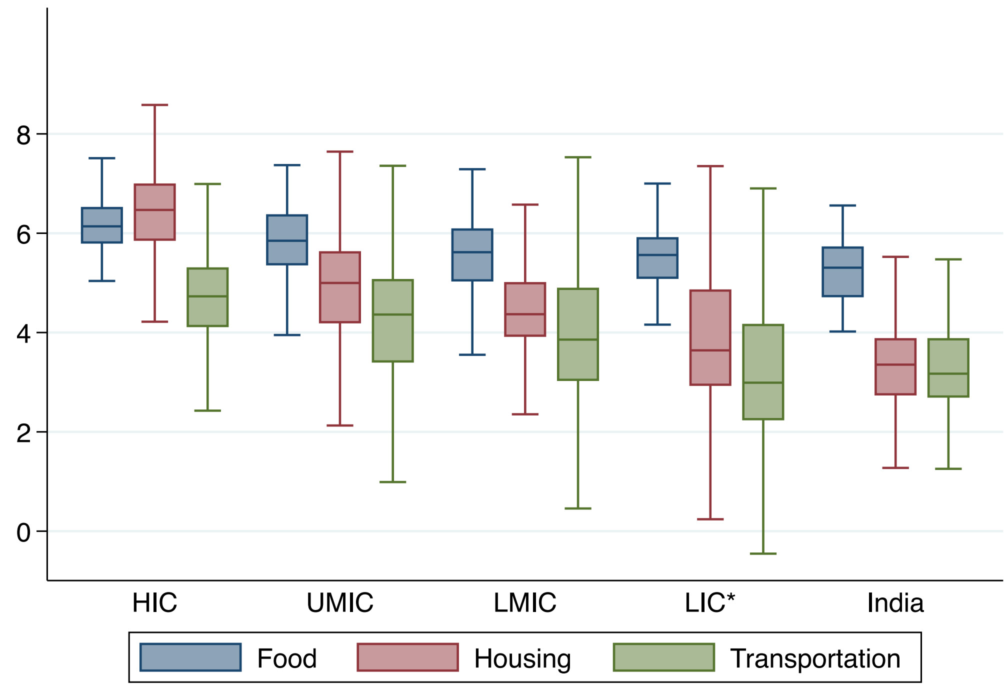
At present the data are available in 23,888 households involving 35,576 participants of whom 13,651 have hypertension. We incorporate the additional data into our estimates of household capacity-to-pay in a sensitivity analysis in the following way. We first calculate the proportion of total household income spent on housing and transportation using the follow-up data. Using this proportion as an adjustment factor, we then estimate expenditures on housing and transportation at baseline by multiplying baseline household income by this adjustment factor. In doing so, we assume these expenditures are constant within a household across time. Capacity-to-pay is then estimated by subtracting food expenditure (from baseline) and the estimated expenditures on housing and transportation from monthly household income.

Capacity-to-pay (CTP) for the *i*th household is, therefore:

$$CTP_i = Inc_i - \left(food_i + \widehat{housing}_i + \widehat{transportation}_i\right)$$

Where CTP_i represents the monthly household capacity-to-pay for household i, Inc_i represents monthly household income, $food_i$ represents monthly household expenditure on food, $\widehat{housing}_i$ represents the estimated monthly expenditure on housing and, $\widehat{transportation}_i$ represents the estimated monthly expenditure on transportation.

Figure 1 Median and interquartile range of household expenditure on food, housing and transportation stratified by country income group 2010 USD, N=53,888 households



Notes: *Excluding India & Zimbabwe

- Y-scale is logarithmic
- Box plots present the median values, upper and lower interquartile ranges, and minimum and maximum values for each location.
- HIC=high income countries; UMIC= upper middle income countries; LMIC= lower middle income countries; LIC= low income countries;

Appendix 4.4 Statistical analysis

In the subset of PURE participants with hypertension and aware of their hypertension diagnosis, we estimated the association between availability and affordability and three dependent variables using multi-level mixed-effects logistic regression models.

The dependent variables are:

1) Use of at least 1 blood-pressure lowering medicine

   ${y_1}_{ihc} = 1$ if participant i, living in household h, situated in community c uses at least one blood pressure lowering medicine

   ${y_1}_{ihc} = 0$ if participant i, living in household h, situated in community c does not use blood pressure lowering medicines

2) Use of combination therapy (2 or more blood-pressure lowering medicines)

   ${y_2}_{ihc} = 1$ if participant i, living in household h, situated in community c uses combination therapy

   ${y_2}_{ihc} = 0$ if participant i, living in household h, situated in community c does not use combination therapy

3) Blood pressure control (BP <140/90 mm Hg)

$y_{3_{ihc}} = 1$ if participant i, living in household h, situated in community c has their blood pressure controlled

$y_{3_{ihc}} = 0$ if participant i, living in household h, situated in community c does not have their blood pressure controlled

We measured availability using three dichotomous variables. These are equal to 1 if all four, at least 3, and at least 2 blood-pressure lowering medicines, respectively, are available for participant i living in household h, in community c, and equal to 0 otherwise. We measured affordability using three dichotomous variables equal to 1 if all four, at least 3, at least 2 blood pressure lowering medicines, respectively, are affordable for participant i living in household h, in community c, and equal to 0 otherwise. The medicines were considered affordable if total monthly costs were less than 20% of household monthly capacity-to-pay. The affordability analyses were restricted to participants living in communities where at least 1 blood-pressure lowering medicine was available. All models were adjusted for age, sex, education, years since hypertension diagnosis, urban versus rural location. We also include a random intercept for each community.

Independent variables:

avail4	=1 if all four classes of blood pressure lowering medicines are available in the community participant i lives in
avail3	=1 if at least 3 blood pressure lowering medicines are available in the community participant i lives in

avail2	=1 if at least 2 blood pressure lowering medicines are available in the community participant *i* lives in
avail1	Reference category = 0 or 1 blood pressure lowering medicine available in the community participant *i* lives in
afford4	=1 all four blood pressure lowering medicines are affordable for participant *i*
afford3	=1 at least 3 blood pressure lowering medicines are affordable for participant *i*
afford2	=1 at least 2 blood pressure lowering medicines are affordable for participant *i*
afford1	reference category = 0 or 1 blood pressure lowering medicines are affordable for participant *i*
age	in years (continuous)
sex	male=1
education1	If participant attended secondary school =1
education2	If participant attended university or trade school =1
education 3	Reference category = no education, primary education or unknown education level
years since hypertension diagnosis 1	=1 if diagnosis was between 2-5 years
years since hypertension diagnosis 2	=1 if diagnosis was greater than 5 years
years since hypertension diagnosis 3	Reference category if diagnosis <2 years
geographic location	=1 if rural

Appendix 4.5

Table 1 Availability of blood pressure lowering medicines by drug class in 626 PURE communities N(%)								
		Total Number of Communities	**ACE Inhibitors**	**ß - blockers**	**Calcium Channel Blocker**	**Diuretics**	**Statins**	**Metformin**
HIC		**115**	**113 98.3%**	**112 97.4%**	**112 97.4%**	**109 94.8%**	**110 95.7%**	**113 98.3%**
	Urban	**84**	82 97.6%	81 96.4%	81 96.4%	78 92.9%	82 97.6%	82 97.6%
	Rural	**31**	31 100.0%	31 100.0%	31 100.0%	31 100.0%	28 90.3%	31 100.0%
UMIC		**126**	**102 81.0%**	**110 87.3%**	**104 82.5%**	**92 73.0%**	**107 84.9%**	**104 82.5%**
	Urban	**66**	56 84.8%	61 92.4%	58 87.9%	51 77.3%	61 92.4%	56 84.8%
	Rural	**60**	46 76.7%	49 81.7%	46 76.7%	41 68.3%	46 76.7%	48 80.0%
LMIC		**227**	**182 80.2%**	**156 68.7%**	**120 52.9%**	**145 63.9%**	**132 58.1%**	**175 77.1%**
	Urban	**112**	102 91.1%	89 79.5%	70 62.5%	79 70.5%	85 75.9%	106 94.6%
	Rural	**115**	80 69.6%	67 58.3%	50 43.5%	66 57.4%	47 40.9%	69 60.0%
LIC*		**68**	**16 23.5%**	**57 83.8%**	**47 69.1%**	**25 36.8%**	**38 55.9%**	**44 64.7%**
	Urban	**35**	11 31.4%	30 86.0%	25 71.4%	23 65.7%	24 68.6%	29 82.9%
	Rural	**33**	5	27	22	2	14	15

			15.2%	81.8%	66.7%	6.1%	42.4%	45.5%
India		**90**	**86** **95.6%**	**86** **95.6%**	**85** **94.4%**	**68** **75.6%**	**77** **85.6%**	**88** **97.8%**
	Urban	**38**	37 97.4%	37 97.4%	37 97.4%	29 76.3%	35 92.1%	37 97.4%
	Rural	**52**	49 94.2%	49 94.2%	48 92.3%	39 75.0%	42 80.8%	51 98.1%
Total		**626**	**499** **79.7%**	**521** **83.2%**	**468** **74.8%**	**439** **70.1%**	**464** **74.1%**	**524** **83.7%**
	Urban	**335**	288 86.0%	298 89.0%	271 80.9%	260 77.6%	287 85.7%	310 92.5%
	Rural	**291**	211 72.5%	223 76.6%	197 67.7%	179 61.5%	177 60.8%	214 73.5%

Table 2 Availability of blood pressure lowering medicines by drug class in 626 PURE communities by country N(%)							
Country	**Total Number of Communities**	**ACE Inhibitors**	**ß - blockers**	**Calcium Channel Blocker**	**Diuretics**	**Statins**	**Metformin**
Canada	71	69 97.2	69 97.2	69 97.2	69 97.2	66 93.0	69 97.2
Saudi Arabia	18	18 100	17 94.4	17 94.4	14 77.8	18 100	18 100
Sweden	23	23 100	23 100	23 100	23 100	23 100	23 100
UAE	3	3 100	3 100	3 100	3 100	3 100	3 100
Argentina	20	20 100	20 100	18 90	17 85	19 95	20 100
Brazil	14	14 100	14 100	14 100	14 100	14 100	14 100
Chile	5	5 100	5 100	5 100	5 100	5 100	5 100
Malaysia	35	18	26	23	12	24	20

		51.4	74.3	65.7	34.3	68.6	57.1
Poland	4	4	4	4	4	4	4
		100	100	100	100	100	100
South Africa	10	3	3	2	2	3	3
		30	30	20	20	30	30
Turkey	38	38	38	38	38	38	38
		100	100	100	100	100	100
China	108	75	50	24	46	46	74
		69.4	46.3	22.2	42.6	42.6	68.5
Colombia	58	53	49	48	46	37	46
		91.4	84.5	82.8	79.3	63.8	79.3
Iran	20	20	20	20	20	20	20
		100	100	100	100	100	100
Palestine	41	34	37	28	33	29	35
		82.9	90.2	68.3	80.5	70.7	85.4
Bangladesh	55	11	49	43	22	34	35
		20.0	89.1	78.2	40.0	61.8	63.6
India	90	86	86	85	68	77	88
		95.6	95.6	94.4	75.6	85.6	97.8

Pakistan	4	2 50	4 100	2 50	0 0	3 75	3 75
Tanzania	6	0 0.0	1 16.7	0 0.0	0 0.0	0 0.0	3 50.0
Zimbabwe	3	3 100	3 100	2 66.7	3 100	1 33.3	3 100
Total	626	499 79.7	521 83.2	468 74.8	439 70.1	464 74.1	524 83.7

Blood pressure lowering drug classes include ace-inhibitors (Captopril, Enalapril, Ramipril), ß-blockers (metoprolol, atenolol), calcium channel blocker (amlodipine) and a diuretic (hydrochlorothiazide).

Table 3 The number and proportion of households that cannot afford blood pressure lowering medicines, N=96,785

		No. of Communities	No. of Households	Unable to Afford 1	Unable to Afford 2	Unable to Afford 2 & metformin	Unable to Afford 2 & statin†	Unable to Afford 2 & metformin & statin†	Unable to Afford 3†
HIC		**90**	**10,880**	**28** **0%**	**44** **0%**	**71** **0·7%**	**242** **2%**	**283** **3%**	**102** **1%**
	Urban	**69**	**8,293**	28 0%	40 0%	60 1%	192 2%	224 3%	82 1%
	Rural	**21**	**2,587**	0 0%	4 0%	11 0%	50 2%	59 2%	20 1%
UMIC		**125**	**25,235**	**1421** **6%**	**2987** **12%**	**4765** **19%**	**6477** **26%**	**7790** **31%**	**6055** **24%**
	Urban	**66**	**14,693**	442 3%	1049 7%	1640 11%	2813 19%	3265 22%	2385 16%
	Rural	**59**	**10,542**	979 9%	1938 18%	3125 30%	3664 35%	4525 43%	3670 35%
LMIC		**225**	**40,236**	**2000** **5%**	**2615** **6%**	**4311** **11%**	**8660** **22%**	**10019** **25%**	**3565** **9%**
	Urban	**111**	**20,867**	990 5%	1208 6%	2024 10%	4040 19%	4828 23%	1651 8%
	Rural	**114**	**19,369**	1010 5%	1407 7%	2287 12%	4620 24%	5191 27%	1914 10%
LIC*		**65**	**3,479**	**598**	**1069**	**1366**	**2277**	**2441**	**1194**

				17%	**31%**	**39%**	**75%**	**80%**	**39%**
	Urban	**34**	**1,929**	307 16%	519 27%	669 35%	1065 65%	1204 74%	399 24%
	Rural	**31**	**1,550**	291 19%	550 35%	697 45%	1212 86%	1237 87%	795 56%
India		**89**	**16,955**	**3817** **23%**	**6139** **36%**	**7721** **46%**	**10952** **65%**	**11497** **68%**	**8417** **50%**
	Urban	**38**	**8,473**	696 8%	1492 18%	2025 24%	4201 50%	4372 52%	2578 30%
	Rural	**51**	**8,482**	3121 37%	4647 55%	5696 67%	6751 80%	7125 84%	5839 69%

Abbreviations: HIC = high-income country; UMIC = upper-middle-income country; LMIC= low-middle-income country LIC = low-income country. Categorization of economic level for each Country based on the 2006 information from the World Bank. *Excluding India and Zimbabwe † Tanzania excluded because only two classes of blood-pressure lowering medicines are available and statins are unavailable in the communities studied, resulting in 588 communities and 3045 households

Table 4 Measured characteristics of participants included in the analysis of affordability versus excluded participants								
	HIC		**UMIC**		**LMIC**		**LIC**	
	Included	Excluded	Included	Excluded	Included	Excluded	Included	Excluded
N	14,894	2,404	35,072	7,757	58,874	3,571	31,372	4,303
Mean age (years)	52	54	51	51	51	52	48	49
Females % (n)	53.2 (7,920)	55.6 (1,335)	58.9 (20,655)	60.8 (4,708)	57.9 (34,083)	61.5 (2,194)	56.2 (17,632)	59.3 (2,550)
Current smokers % (n)	14.3 (2,131)	16.1 (380)	22.2 (7,706)	25.1 (1,917)	21.5 (12,454)	17.4 (615)	22.9 (7143)	24.9 (1,068)
Low education[1] % (n)	13.2 (1,969)	9.4 (227)	48.3 (16,940)	64.6 (5,012)	38.9 (22,879)	58.2 (2,077)	51.5 (16,164)	55.4 (2,385)
Hypertension % (n)	39.3 (5,648)	42.1 (958)	49.1 (14,739)	50.4 (3,548)	39.9 (23,118)	35.2 (1,193)	31.9 (9,218)	36.3 (1,365)

[1] low education level is defined as no education, primary education only or unknown education level

Table 5 Type, dose and frequency of blood pressure lowering medicines used to calculate the monthly cost of each drug			
	Target dose	**Standard dose**	**Recommended frequency per day**
	(trial reference)	**(used in analyses)**	
ACE inhibitors			
Captopril	50mg (SAVE trial)[8]	25mg	3
Enalapril	10mg (SOLVD trial)[9]	5mg	2
Ramipril	10mg (HOPE trial)[10]	5mg	1
ß-blockers			
Metoprolol	100mg (MERIT-HF trial)[11]	50mg	2
Atenolol	100mg (ISIS trial)[12]	50mg	1
Calcium Channel Blocker			
Amlodipine	5mg (ALLHAT trial)[13]	5 mg	1
Diuretic			
Hydrochlorothiazide	25mg[14]	25 mg	1
Statins			
Simvastatin	40mg (HPS trial)[15]	20 mg	1
Atorvastatin	10 mg (ASCOT trial)[16]	20 mg	1

*If the medicine was available at the pharmacy for a dose different from the specified standard dose, the cost was adjusted based on the assumption that doubling the dose increased the cost by one-and-half times

Table 6 Monthly household capacity-to-pay (2010 US dollars), and monthly costs (2010 US dollars) of blood pressure lowering medicines by urban and rural location

	No. of Comm-unities	No. of House holds	Median capacity-to-pay (IQR)	Median capacity-to-pay (housing and transportation costs incorporated) (IQR)[a]	Monthly cost of the lowest cost anti-hyp. medicine	Monthly cost of the 2 lowest cost anti-hyp. medicines	Monthly cost of the 2 lowest cost anti-hyp. + metformin	Monthly cost of the 2 lowest cost anti-hyp. + lowest cost statin†	Monthly cost of the 2 lowest cost anti-hyp. + metformin & lost cost statin†	Monthly cost of the 3 lowest cost anti-hyp. medicines †
HIC	**90**	**10,880**	**2545 (1617, 3585)**	**2056 (1195, 2976)**	**4 (2, 9)**	**17 (3, 25)**	**26 (7, 35)**	**44 (5, 70)**	**52 (9, 84)**	**33 (6, 49)**
Urban	**69**	**8,293**	2653 (1683, 3670)	2137 (1277, 3069)	7 (2, 11)	19 (3, 29)	28 (7, 41)	47 (5, 78)	53 (9, 94)	33 (6, 54)
Rural	**21**	**2,587**	2350 (1435, 3354)	1731 (989, 2618)	4 (2, 4)	16 (8, 20)	25 (18, 28)	40 (33, 52)	50 (37, 58)	31 (22, 36)
UMIC	**125**	**25,235**	**290 (115, 671)**	**171 (49, 365)**	**4 (2, 6)**	**12 (8, 14)**	**18 (11, 20)**	**21 (18, 35)**	**27 (23, 43)**	**22 (20, 24)**
Urban	**66**	**14,693**	416 (173, 980)	212 (72, 485)	5 (2, 6)	13 (9, 15)	18 (14, 21)	25 (20, 38)	29 (25, 42)	22 (20, 26)
Rural	**59**	**10,542**	183 (72, 383)	131 (34, 280)	4 (1, 5)	11 (4, 13)	18 (7, 20)	20 (11, 34)	26 (14, 43)	22 (15, 24)
LMIC	**225**	**40,236**	**173 (75, 338)**	**137 (45, 277)**	**0·09 (0·09, 0·9)**	**0·33 (0·2, 3)**	**4 (0·5, 10)**	**8 (3, 18)**	**8 (5, 24)**	**1 (0·4, 8)**
Urban	**111**	**20,867**	242 (117, 432)	177 (62, 330)	0·2 (0·09, 2)	0·5 (0·3, 5)	4 (0·8, 14)	9 (2, 24)	11 (3, 32)	4 (0·7, 11)
Rural	**114**	**19,369**	121 (49, 228)	100 (35, 209)	0·09 (0·09, 0·9)	0·3 (0·2, 2)	1 (0·5, 4)	8 (8, 9)	8 (8, 12)	1 (0·4, 4)
LIC*	**68**	**3,782**	**52 (21,104)**	**22 (0·2, 63)**	**0·7 (0·7, 1)**	**2 (2, 2)**	**6 (4, 7)**	**24 (20, 24)**	**24 (24, 28)**	**6 (5, 6)**
Urban	**35**	**2,011**	78 (29, 137)	24 (0, 79)	0·7 (0·7, 1)	2 (2, 2)	6 (5, 8)	20 (20, 24)	26 (24, 28)	5 (5, 6)

Rural	**33**	**1,771**	32 (13, 78)	22 (7, 56)	0·7 (0·7, 0·7)	2 (2, 2)	2 (2, 7)	24 **(24, 24)**	24 (24, 28)	6 (6, 6)
India	89	**16,955**	**61 (18, 218)**	**41 (0, 155)**	**3 (2, 4)**	**9 (6, 10)**	**12 (10, 13)**	**30 (24, 38)**	**33 (27, 42)**	**15 (12, 16)**
Urban	**38**	**8,473**	167 (52, 485)	130 (35, 395)	3 (2, 4)	7 (7, 9)	10 (10, 13)	34 (27, 39)	38 (31, 43)	15 (13, 17)
Rural	**51**	**8,482**	26 (7, 75)	16 (0, 71)	4 (2, 4)	9 (6, 10)	12 (9, 13)	30 (11, 30)	33 (14, 34)	16 (11, 16)
Overall	**597**	**97,088**	**204 (70, 535)**	**169 (42, 462)**	**2 (0·4, 4)**	**5 (2, 11)**	**10 (4, 18)**	**21 (8, 33)**	**26 (9, 39)**	**11 (4, 22)**
Urban	**319**	**54,337**	338 (127, 817)	262 (80, 775)	2 (0·7, 5)	6 (2, 13)	13 (6, 20)	24 (9, 39)	28 (12, 45)	13 (5, 23)
Rural	**278**	**42,751**	109 (36, 264)	98 (25, 262)	0·9 (0·09, 4)	3 (0·9, 10)	7 (2,14)	20 (8, 30)	24 (8, 33)	8 (2, 16)

Notes: abbreviations: HIC = high-income country; UMIC = upper-middle-income country; LMIC= low-middle-income country LIC = low-income country. Categorization of economic level for each country based on the 2006 information from the World Bank. Costs are median (IQR), medicines include ACE-inhibitors, ß- blockers, calcium-channel blocker, and diuretics*Capacity-to-pay and medicine costs exclude India, medicine costs also exclude Zimbabwe because purchasing power parity values were unavailable † Tanzania excluded because only two classes of blood-pressure lowering medicines are available and statins are unavailable in the communities studied, resulting in 588 communities. [a]Capacity-to-pay estimates based on a subset of PURE participants (N=23,888) with information on housing and transportation costs which were incorporated into capacity-to-pay calculation

Table 7 The number and proportion of households that cannot afford blood pressure lowering medicines by Country, N=96,785

Country*	No. of Households	Unable to Afford 1	Unable to Afford 2	Unable to Afford 2 & metformin	Unable to Afford 2 & statin†	Unable to Afford 2 & metformin & statin†	Unable to Afford 3†
Canada	6555	15 0.2%	23 0.4%	42 0.6%	102 1.6%	130 2.0%	55 0.8%
Saudi Arabia	939	11 1.2%	12 1.3%	15 1.6%	26 2.8%	29 3.1%	25 2.7%
Sweden	2429	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
UAE	957	2 0.2%	9 0.9%	14 1.5%	114 11.9%	124 13.0%	22 2.3%
Argentina	2207	170 7.7%	296 13.4%	595 27.0%	1306 59.2%	1475 66.8%	706 32.0%
Brazil	3710	5 0.1%	33 0.9%	132 3.6%	182 4.9%	321 8.7%	148 4.0%
Chile	2236	59 2.6%	63 2.8%	267 11.9%	430 19.2%	563 25.2%	194 8.7%
Malaysia	10501	483 4.6%	1212 11.5%	1997 19.0%	2558 24.4%	3194 30.4%	3016 28.7%
Poland	1499	2 0.1%	2 0.1%	3 0.2%	5 0.3%	6 0.4%	3 0.2%
South Africa	2413	692 28.7%	1333 55.2%	1644 68.1%	1854 76.8%	1966 81.5%	1802 74.7%

Turkey	2669	10 0.4%	48 1.8%	127 4.8%	142 5.3%	265 9.9%	186 7.0%
China	30519	701 2.3%	832 2.7%	1745 5.7%	5252 17.2%	6213 20.4%	1175 3.9%
Colombia	5165	837 16.2%	1319 25.5%	2082 40.3%	2931 56.7%	3309 64.1%	1907 36.9%
Iran	2993	61 2.0%	61 2.0%	61 2.0%	61 2.0%	61 2.0%	61 2.0%
Palestine	1559	401 25.7%	403 25.8%	423 27.1%	416 26.7%	436 28.0%	422 27.1%
Bangladesh	2002	139 6.9%	142 7.1%	358 17.9%	1431 71.5%	1578 78.8%	499 24.9%
India	16955	3817 22.5%	6139 36.2%	7721 45.5%	10952 64.6%	11497 67.8%	8417 49.6%
Pakistan	1043	213 20.4%	516 49.5%	584 56.0%	846 81.1%	863 82.7%	695 66.6%
Tanzania	434	246 56.7%	411 94.7%	424 97.7%	n/a	n/a	n/a

*Excluding Zimbabwe † Tanzania excluded because only two classes of blood-pressure lowering medicines are available and statins are unavailable in the communities studied

Table 8 The number and proportion of households that cannot afford blood pressure lowering medicines at different thresholds to define what is unaffordable, N=96,785								
Capacity-to-pay threshold		**No. of Households**	**Unable to Afford 1**	**Unable to Afford 2**	**Unable to Afford 2 & metformin**	**Unable to Afford 2 & statin†**	**Unable to Afford 2 & metformin & statin†**	**Unable to Afford 3†**
10% or more	HIC	10,880	34	115	213	648	769	323
			0.3%	1.1%	2.0%	6.0%	7.1%	3.0%
	UMIC	25,235	2175	5436	7810	10138	11678	10008
			8.6%	21.5%	30.9%	40.2%	46.3%	39.7%
	LMIC	40,236	2333	3398	6611	13658	15567	5105
			5.8%	8.4%	16.4%	33.9%	38.7%	12.7%
	LIC*	3,479	835	1453	1962	2758	2821	1685
			24.0%	41.8%	56.4%	90.6%	92.6%	48.4%
	India	16,955	5316	8461	10079	12951	13431	10915
			31.4%	49.9%	59.4%	76.4%	79.2%	64.4%
20% or more	HIC	10,880	28	44	71	242	283	102
			0.3%	0.4%	0.7%	2.2%	2.6%	0.9%
	UMIC	25,235	1421	2987	4765	6477	7790	6055
			5.6%	11.8%	18.9%	25.7%	30.9%	24.0%
	LMIC	40,236	2000	2615	4311	8660	10019	3565
			5.0%	6.5%	10.7%	21.5%	24.9%	8.9%
	LIC*	3,479	598	1069	1366	2277	2441	1194
			17.2%	30.7%	39.3%	74.8%	80.2%	34.3%
	India	16,955	3817	6139	7721	10952	11497	8417

			22.5%	36.2%	45.5%	64.6%	67.8%	49.6%
30% or more	HIC	10,880	27	35	41	121	157	55
			0.2%	0.3%	0.4%	1.1%	1.4%	0.5%
	UMIC	25,235	1216	2148	3281	4668	5840	4339
			4.8%	8.5%	13.0%	18.5%	23.1%	17.2%
	LMIC	40,236	1874	2322	3488	6445	7580	2997
			4.7%	5.8%	8.7%	16.0%	18.8%	7.4%
	LIC*	3,479	519	901	1087	1942	2030	868
			14.9%	25.9%	31.2%	63.8%	66.7%	24.9%
	India	16,955	3273	4822	6342	9614	10181	6950
			19.3%	28.4%	37.4%	56.7%	60.0%	41.0%
40% or more	HIC	10,880	26	30	37	71	90	42
			0.2%	0.3%	0.3%	0.7%	0.8%	0.4%
	UMIC	25,235	1130	1704	2608	3601	4572	3330
			4.5%	6.8%	10.3%	14.3%	18.1%	13.2%
	LMIC	40,236	1841	2176	3045	5456	6307	2691
			4.6%	5.4%	7.6%	13.6%	15.7%	6.7%
	LIC*	3,479	476	804	950	1591	1709	780
			13.7%	23.1%	27.3%	52.2%	56.1%	22.4%
	India	16,955	2823	4201	5482	8600	9234	6057
			16.6%	24.8%	32.3%	50.7%	54.5%	35.7%

Abbreviations: HIC = high-income country; UMIC = upper-middle-income country; LMIC= low-middle-income country LIC = low-income country. Categorization of economic level for each country based on the 2006 information from the World Bank. *Excluding India and Zimbabwe † Tanzania excluded because only two classes of blood-pressure lowering medicines are available and statins are unavailable in the communities studied, resulting in 588 communities and 3045 households

Table 9 The number and proportion of households that cannot afford§ blood pressure lowering medicines using the lowest cost blood pressure lowering medicine as a proportion of household income, N=96,785

	No. of Households	Unable to Afford 1	Unable to Afford 2	Unable to Afford 2 & metformin	Unable to Afford 2 & statin†	Unable to Afford 2 & metformin & statin†	Unable to Afford 3†
HIC	10,880	0	0	0	21	32	0
		0.0%	0.0%	0.0%	0.2%	0.3%	0.0%
UMIC	25,235	255	599	1386	2520	3774	2141
		1.0%	2.4%	5.5%	10.0%	15.0%	8.5%
LMIC	40,236	1	106	589	2918	3887	449
		0.0%	0.3%	1.5%	7.3%	9.7%	1.1%
LIC*	3,479	254	475	616	1536	1730	898
		7.3%	13.7%	17.7%	44.2%	49.7%	25.8%
India	16,955	8	859	2229	6844	7902	3035
		0.0%	5.1%	13.1%	40.4%	46.6%	17.9%

Abbreviations: HIC = high-income country; UMIC = upper-middle-income country; LMIC = low-middle-income country LIC= low-income country. Categorization of economic level for each Country based on the 2006 information from the World Bank. *Excluding India and Zimbabwe † Tanzania excluded because only two classes of blood-pressure lowering medicines are available and statins are unavailable in the communities studied, resulting in 588 communities. § In calculating affordability we use the cost of the lowest cost medicine(s). For consistency, we use the 20% threshold; if the lowest cost BP lowering medicine(s) cost more than 20% of household income, it is considered unaffordable.

Table 10 Adjusted and unadjusted associations between availability and affordability[§] and use of at least one blood pressure lowering medicine, use of combination therapy, and blood pressure control in participants with known hypertension		
	Odds Ratio (95% CI)	
Availability, N= 33,035	Unadjusted	Adjusted
Effect on use of at least 1 blood-pressure lowering medicine		
4 available	2·44 (1·74, 3·44)	2·23 (1·59, 3·12)
3 available	0·72 (0·46, 1·14)	0·74 (0·47, 1·15)
2 available	0·91 (0·55, 1·52)	0·93 (0·56, 1·52)
0 or 1 available	reference	reference
Effect on use of combination therapy (2 or more blood-pressure lowering medicines)		
4 available	1·52 (1·13, 2·06)	1·53 (1·13, 2·07)
3 available	0·51 (0·33, 0·77)	0·54 (0·36, 0·81)
2 available	0·78 (0·49, 1·24)	0·82 (0·52, 1·30)
0 or 1 available	Reference	Reference
Effect on blood pressure control (BP <140/90 mm Hg)		
4 available	2·39 (1·94, 2·93)	2·06 (1·69, 2·50)
3 available	1·43 (1·09, 1·88)	1·32 (1·02, 1·71)
2 available	0·88 (0·64, 1·20)	0·80 (0·59, 1·08)
0 or 1 available	reference	reference
Affordability[*], N=26,161		
Effect on use of at least 1 anti-hypertensive		
4 affordable	1·44 (1·27, 1·64)	1·42 (1·25, 1·62)

3 affordable	1·28 (1·11, 1·47)	1·26 (1·10, 1·46)
2 affordable	1·06 (0·91, 1·23)	1·03 (0·88, 1·20)
0 or 1 affordable	reference	reference
Effect on use of combination therapy (2 or more blood-pressure lowering medicines)		
4 affordable	1·26 (1·08, 1·47)	1.26 (1.08, 1.47)
3 affordable	1·26 (1·06, 1·49)	1·23 (1·03, 1·46)
2 affordable	0·99 (0·82, 1·21)	0·97 (0·80, 1·18)
0 or 1 affordable	reference	reference
Effect on blood pressure control (BP less than 140/90 mm Hg)		
4 affordable	1·20 (1·06, 1·37)	1·13 (1·00, 1·28)
3 affordable	1·02 (0·88, 1·18)	0·98 (0·85, 1·14)
2 affordable	1·00 (0·85, 1·18)	0·99 (0·84, 1·16)
0 or 1 affordable	reference	reference

Adjusted for: age, sex, education, years since hypertension diagnosis, urban versus rural location; clustered at the community level. * Analysis restricted to participants living in communities where at least 1 anti-hypertensive is available

§In calculating affordability we use the cost of the lowest cost medicine(s)

Table 11 Associations between availability and use of at least one blood pressure lowering medicine, use of combination therapy, and blood pressure control in participants with known hypertension

	1 Odds Ratio [95% CI]	2 Odds Ratio [95% CI]	3 Odds Ratio [95% CI]
Outcome	Use of at least 1 antihypertensive	Use of combination therapy	Effect of on blood pressure control
0 or 1 antihypertensive available	reference	reference	reference
2 antihypertensives available	0.93	0.82	0.80
	[0.56,1.52]	[0.52,1.30]	[0.59,1.08]
3 antihypertensives available	0.74	0.54**	1.32*
	[0.47,1.15]	[0.36,0.81]	[1.02,1.71]
4 antihypertensives available	2.23***	1.53**	2.06***
	[1.59,3.12]	[1.13,2.07]	[1.69,2.50]
Age (years)	1.04***	1.02***	1.00
	[1.04,1.04]	[1.02,1.03]	[1.00,1.00]
Male	0.79***	0.98	0.76***
	[0.75,0.84]	[0.92,1.04]	[0.72,0.81]
Community location rural	0.78*	0.96	0.65***
	[0.61,1.00]	[0.78,1.20]	[0.56,0.74]
>1 yr to 5 yrs since hypertension diagnosis	1.78***	1.91***	1.23***
	[1.64,1.93]	[1.73,2.11]	[1.13,1.34]
>5 yrs since hypertension diagnosis	2.17***	2.81***	1.06
	[2.00,2.35]	[2.55,3.11]	[0.98,1.16]
Secondary school graduate	1.26***	1.04	1.17***
	[1.18,1.35]	[0.97,1.13]	[1.09,1.26]
University College or trade school graduate	1.37***	0.89*	1.41***
	[1.25,1.50]	[0.81,0.98]	[1.29,1.54]
_cons	0.062***	0.023***	0.19***
	[0.042,0.091]	[0.016,0.034]	[0.15,0.26]
lns1_1_1			
_cons	1.36***	1.14**	0.66***
	[1.26,1.47]	[1.04,1.24]	[0.60,0.72]

N	33035	33035	33035

* p<0.05, ** p<0.01, *** p<0.001

reference categories are female, community location urban, less than 2 years since hypertension diagnosis, low educational defined as no education, primary education only or unknown educational level

Table 12 Associations between affordability and use of at least one blood pressure lowering medicine, use of combination therapy, and blood pressure control in participants with known hypertension

	1 Odds Ratio [95% CI]	2 Odds Ratio [95% CI]	3 Odds Ratio [95% CI]
Outcome variable	Use of at least 1 antihypertensive	Use of combination therapy	Effect of on blood pressure control
0 or 1 antihypertensive affordable	reference	reference	reference
2 antihypertensives affordable	1.03	0.97	0.99
	[0.88,1.20]	[0.80,1.18]	[0.84,1.16]
3 antihypertensives affordable	1.26**	1.23*	0.98
	[1.10,1.46]	[1.03,1.46]	[0.85,1.14]
4 antihypertensives affordable	1.42***	1.26**	1.13
	[1.25,1.62]	[1.08,1.47]	[1.00,1.28]
Age (years)	1.04***	1.02***	1
	[1.04,1.04]	[1.02,1.03]	[1.00,1.00]
Male	0.79***	1	0.77***
	[0.74,0.84]	[0.93,1.06]	[0.73,0.82]
Community location rural	0.70*	0.84	0.61***
	[0.53,0.92]	[0.66,1.07]	[0.51,0.72]
>1 yr to 5 yrs since hypertension diagnosis	1.87***	1.91***	1.21***
	[1.71,2.05]	[1.70,2.13]	[1.10,1.32]
>5 yrs since hypertension diagnosis	2.23***	2.77***	1.05
	[2.04,2.44]	[2.48,3.09]	[0.95,1.14]
Secondary school graduate	1.24***	1.01	1.10*
	[1.14,1.34]	[0.93,1.10]	[1.02,1.20]
University College or trade school graduate	1.31***	0.86**	1.32***
	[1.18,1.46]	[0.77,0.95]	[1.20,1.46]
_cons	0.074***	0.024***	0.30***
	[0.055,0.10]	[0.018,0.033]	[0.23,0.40]
lns1_1_1			
_cons	1.47***	1.19***	0.75***
	[1.35,1.59]	[1.08,1.31]	[0.69,0.83]

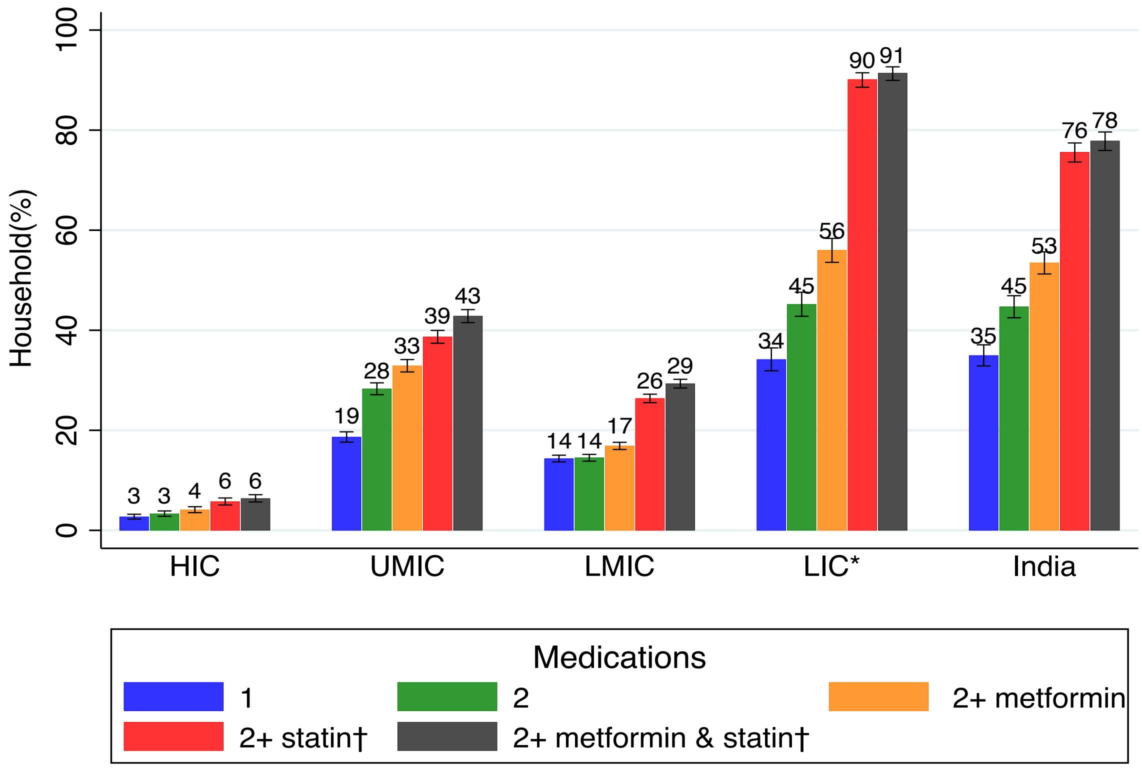
N	26161	26161	26161

* p<0.05, ** p<0.01, *** p<0.001
reference categories are female, community location urban, less than 2 years since hypertension diagnosis, low education defined as no education, primary education only or unknown educational level. Analyses restricted to participants living in communities where at least 1 blood pressure lowering medicine is available

Here we describe the model estimates in greater detail. Appendix 4.5 Table 11 and 12 display the coefficient estimates for the fully adjusted models displayed in Figure 4.3. The relationship between participant characteristics and the three outcomes (use of at least 1 antihypertensive, use of 2 or more, and blood-pressure control) are similar in both the availability and affordability models.

In general, the covariate estimates are highly significant and are in the expected direction. Increasing age increases the odds of using antihypertensives ($p<0.001$), but has no effect on blood-pressure control. Men are less likely to use at least one antihypertensive and have their blood-pressure controlled ($p<0.001$), however participant sex has no effect on using 2 or more antihypertensives. Participants living in rural areas are less likely to use antihypertensives and have their blood-pressure controlled. Participants with a secondary school education are more likely to use at least one antihypertensive ($p<0.001$) and have their blood-pressure controlled ($p<0.05$), but having a secondary school education has no effect on using two or more antihypertensives. This relationship holds true for participants with a college or trade school education, however participants with a college or trade school education are less likely to use 2 or more antihypertensives ($p<0.01$).

Figure 1 Proportion of households that cannot afford one, two, two BP lowering medicines and metformin, two BP lowering medicines and a statin, and two BP lowering medicines, metformin, and a statin[§] using a 20% of capacity-to-pay threshold, (incorporating housing and transportation costs into capacity-to-pay calculations), N = 23,888 households



HIC= high income countries; UMIC=upper middle income countries; LMIC=lower middle income countries; LIC*= low income countries excluding India & Zimbabwe † Tanzania excluded because statins are unavailable. BP= blood pressure

§In calculating affordability we use the cost of the lowest cost medicine(s)

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Chapter 5 Conclusion

The three chapters in this thesis contribute to a greater understanding of the measurement and interpretation of health inequalities. In this concluding chapter, I summarize the key findings for each of the three studies, highlight their novel contributions, and conclude with their policy implications.

Key findings and novel contributions:

Chapter 2 presents a comprehensive review and critical examination of the literature on the technical and normative properties of the concentration index based indices (CI-based). As a conceptual study, it goes beyond providing a review, commentary, and critique of the current literature by linking several important concepts, at times from different disciplines, to elucidate the properties of the CI-based indices. To relate these properties to normative assumptions on fairness, I relate several strands of the current literature using clear and simple descriptions accompanied by numerous empirical examples and figures. Previous studies primarily focused on the technical properties or a specific normative concern, such as the relevance of the mirror property and whether an index should be relative or absolute (see for example, Erreygers and Van Ourti, 2011; Kjellsson and Gerdtham, 2013). The integration of the current literature is necessary because the central problem this chapter aims to address is understanding the differences among and conditions for the use of the various CI-based indices. By carefully considering the properties of the indices, analysts can determine for themselves which indices are appropriate for their context. The review of current research practice serves to empirically illustrate how well current research practice aligns with properties of the indices used. The findings from this review demonstrate that researchers often fail to provide meaningful interpretations of the index estimates, and in some cases, these indices are misused or misinterpreted.

An added contribution of this chapter is the development of a framework, in the form of a series of questions, for choosing among the CI-based indices. This framework alongside the comprehensive table that summarizes the indices technical and normative properties functions as a guide for a) applied researchers in choosing inequality measures that have the normative properties they seek, and b) policy researchers and analysts to help them be more critical consumers of studies that use these measurement tools. Chapter 2, therefore, helps address the gap between the requirements of the CI-based indices and current research practice.

Chapter 3 examines inequality aversion preferences using a stated preference experiment that was implemented among a sample of the general public in Ontario, Canada. Using the responses from 1,964 participants, this study presents novel findings on the public's attitudes toward health inequality, income inequality, and income-related health inequality.

The principal finding from this chapter is that attitudes toward inequality are domain-specific. Inequality aversion (IA) preferences overall (i.e., using the mean and median as measures of central tendency) and by participants' socio-demographic characteristics, were different across domains. However, within each domain, there was little systematic variability in mean IA by participants' socio-demographic characteristics. This finding suggests that public attitudes toward inequality reflect values that appear to be independent of their socio-demographic characteristics. The bi-modal distribution of preferences toward health inequality, where approximately half of the participants display aversion toward health inequalities and the other half do not, has not been previously reported. Although this finding was initially puzzling, the descriptive qualitative analysis of participants' comments confirmed the quantitative interpretation that some people have strong preferences for equality in health whereas others have strong preferences for a longer life expectancy, especially when access to health care is not a factor.

Prior to this study, the literature examining inequality aversion preferences were isolated to a specific domain, either income inequality often published in general economics journals, or health inequality often published in health economics or health services research journals. Chapter 3 presents the first study to elicit aversion toward inequality across three domains that are the focus of much inequality research (i.e., health inequality, income inequality, and income-related health inequality). Testing for domain-specific preferences is important because commonly used measurement tools for assessing inequality, such as the Gini coefficient, are used across domains, and analysts often assume that inequality aversion preferences do not vary. If attitudes toward inequality are domain specific, assessments of inequality should reflect these differences if the estimates of inequality are to be relevant. An added novelty of this study is the incorporation of participant's explanations of their choices. Not only does the qualitative analysis of these comments provides further validation of the inequality estimates, it also enhances the quantitative findings by describing the more deeply held normative theories participants used when making their choices. The two methods, intended to serve different purposes, when taken together allow for a more meaningful understanding on the publics' attitudes toward inequality. Moreover, combining the quantitative and qualitative results allows for a more accurate interpretation of inequality aversion preferences since participant's explanations are used to interpret the results.

Chapter 4 presents insights about some of the causes of global health inequalities that result from unequal access to blood-pressure-lowering medicines in 20 countries at varying levels of economic development. This chapter describes the availability and affordability of four commonly used classes of blood-pressure-lowering medicines: diuretics, angiotensin-converting enzyme (ACE) inhibitors, calcium-channel blockers, and ß-blockers. Multi-level mixed effects logistic models were used to assess the association between usage and availability and affordability of these medicines, and blood pressure control among a subset of participants with hypertension that were aware of their diagnosis. Three sets of findings from this study are worth highlighting. First, a large proportion of communities in low and middle-income countries do not have access to more than one blood-pressure-lowering medicine. When these medicines were available, they were often not affordable. This finding is important because most individuals with hypertension require at least two blood-pressure-lowering medicines to adequately control their blood pressure. Second, the monthly cost of the lowest, lowest two and lowest 3 blood-pressure-lowering medicines were highest in absolute terms in high-income countries. Because of the much higher household incomes in high-income countries, this monthly cost constituted a lower proportion of household capacity-to- pay (<1%). The monthly cost of the lowest, lowest two and lowest 3 blood-pressure-lowering medicines in upper-middle income countries was similar to high-income countries but constituted a higher fraction of household capacity-to-pay in upper-middle income countries which was largely driven by lower household incomes. Third, positive and statistically significant associations were found between availability and affordability of multiple blood-pressure-lowering medicines and blood pressure control. Taken together, these results suggest that multiple blood-pressure-lowering drug classes need to be available and affordable to i) improve hypertension control, and ii) to potentially reduce the health differences attributed to unequal access to these medicines.

This chapter adds to the existing literature on access to essential medicines by establishing a link between availability and affordability of blood-pressure-lowering medicines to both the use of these medicines and blood pressure control. Prior to this study, data quality on the availability and affordability of blood-pressure-lowering medicines in low- and low-middle income countries was poor or simply unknown (Wirtz and Moucheraud, 2017). This chapter addresses this important gap in the literature by presenting findings at the community, household, and individual level using data from standardized questionnaires and validated tools. To put this large scale-epidemiological study into context, previous studies on hypertension drug costs used median procurement prices from the international reference price index created by Management Sciences for Health for a select number of developing countries. Often, the countries that were part of the analyses of studies were different from the countries included in the international reference price index (Attaei and Yusuf, 2017). Moreover, there are marked differences between prices charged to patients and procurement prices, which limits the utility of these studies in informing policy. In doing so, these studies have underestimated the cost of blood-pressure-lowering medicines thereby downplaying the affordability problem of essential medicines.

Policy relevance:

In addition to providing novel insights to the current body of knowledge, the findings from chapters 2-4 have policy-relevant implications.

The CI-based indices, which are the focus of Chapter 2, remain the most popular tools for estimating socio-economic-related health inequalities. In highlighting drawbacks of current research practice, while providing a guide for researchers and policy-analysts on how to use and interpret these indices, this chapter suggests improvements in assessments of socio-economic-related health inequality. Chapter 3 stems from the observation that almost all measurement tools used for assessing inequalities make inequality aversion assumptions. In providing inequality aversion estimates that are empirically derived using a sample of the general public, we can better understand the extent to which the current income or health distribution falls short of the ideal distributions. Moreover, in understanding public attitudes toward inequalities in health and income, we can devise policies and programs that are not only effective but also likely to be supported by the public. In addition, given the increased interest in explicitly incorporating inequality aversion preferences into economic evaluations such as cost-effectiveness analyses, the empirically derived estimates of inequality aversion can inform these other applications. The results of Chapters 2 and 3 are particularly timely given the increased prominence of assessing inequalities by governments, international agencies, and researchers, along with efforts to communicate the evidence on the levels and trends in inequality to both policy-makers and the general public.

The results from chapter 4 i) demonstrate that access to essential medicines remains a public health challenge, (the medicines considered in the analyses are all listed on the WHO model list of essential medicines) and ii) provide an empirical illustration on how country-specific policies can play an important role in either countering or exacerbating some of the health differences. Hypertension, which affects roughly a billion people worldwide, is a modifiable risk factor for cardiovascular diseases. However, blood pressure control is poor, and use of blood-pressure-lowering medicines remains suboptimal. The results from chapter 4 are therefore also relevant to public policies targeted at reducing the global burden of cardiovascular diseases (CVD) particularly the goal of 25% reduction in premature CVD deaths by 2025.

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