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Avoiding blindness to health status in health achievement and health inequality measurement

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ABSTRACT

The concentration index, being focused on the socioeconomic dimension of health inequality and overlooking aversion to pure health inequality, can produce ethically contestable rankings of health distributions. A health transfer from a sicker but richer individual to healthier but poorer individual will decrease the concentration index. This paper presents a new class of health inequality indices that avoid this limitation by trading off socioeconomic-related health inequality against pure health inequality.

1. Introduction

A large body of the health inequality measurement literature is based on the accumulated knowledge in income inequality measurement. Early contributions to health inequality measurement by Le Grand (1989) and Le Grand and Rabin (1986) proposed the well known Gini coefficient as measure of *pure* health inequality (e.g., inequality in mortality). However, as the decision maker may often be interested in the socioeconomic dimension of health inequalities (rather than pure health inequalities), the use of the concentration index is considered more appropriate (see Wagstaff et al., 1989; and Wagstaff et al., 1991). As a result, a large body of the literature is using the concentration index and it is now a widely accepted measure of socioeconomic health inequality. While the theoretical welfare foundations of income inequality measurement has led to many contributions in the social choice literature (for a survey, see Dutta, 2002), exploration of the welfare foundations of health inequality measurement is still scarce. Stecklov and Bommier (2002), Fleurbaey (2006) and Bleichrodt and van Doorslaer (2006) are notable exceptions.

In the context of income inequality measurement, Atkinson (1970) argues that the “examination of the social welfare functions implicit in these (income inequality) measures shows that in a number of cases they have properties which are unlikely to be acceptable, and in general there are no grounds for believing that they would accord with social values” (p. 262). Based on this idea, Bleichrodt and van Doorslaer (2006) derived social welfare functions that are implicit in the health Gini (pure health inequality) and the health concentration (socioeconomic health inequality) indices. As Atkinson (1970), they argue that concern with (health) inequality implies an underlying social judgment that reduction in these inequalities should increase social welfare. In their theoretical investigation the authors identify formally two health transfer principles: the *principle of health transfers* and the *principle of income-related health transfers*.

The *principle of health transfers* is imbedded in the health Gini measure. It holds if a transfer of health from someone who is healthier to someone who is less healthy does not decrease social welfare as long as the ranks of the two individuals remains unchanged.[1] One may object that these transfers are desirable when

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[1] It is important to note that although a unit health *per se* is not transferable, health policies can influence individuals' health levels. As such, they act as if they were transferring a unit of health from one individual to another.

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the healthier person is poor and the less healthy person is rich. This is why Wagstaff et al. (1989) highlight the importance of turning the attention towards socioeconomic health inequality rather than pure health inequality.

Socioeconomic health inequality measures (e.g., the health concentration indices) are based on the *principle of income-related health transfers*. This ethical principle holds if transferring health from a rich person to a poorer person does not decrease social welfare. However, as pointed by Bleichrodt and van Doorslaer (2006), whether this principle is ethically appealing is contestable. It is possible that transferring health from a person with higher income to a person with a lower income is not desirable if the rich person is in poor health and the difference in income is small. Using an experimental approach, Bleichrodt et al. (2012) investigated the plausibility of the *principle of income-related health transfers* and find that it is systematically violated. Unfortunately, by construction, concentration indices react favorably when a health transfer is made from an individual at a lower rank in the health distribution to a person at a higher rank (regardless of the magnitude of the difference in their health status), provided that the former has a slightly higher income. It follows that this class of socioeconomic health inequality indices, given its mathematical linear rank dependent structure (i.e., obeys the *principle of income-related health transfer*), overlooks individual heterogeneity in the income-health relation (i.e. non-monotonicity in the income-health gradient when there is more than one individual) and thus exhibits *blindness to health status*.[2] To our knowledge, to this date, no practical measurement solution has been offered to circumvent this problem.[3] We believe that it is important to understand the source of this measurement issue and address it, as overlooking it may lead to health policy recommendations that do not concord with the values of many, and even a majority, in society (i.e., a health transfer from a less healthy individual to a healthier individual should not be evaluated as an improvement in the distribution of health).

This paper contributes to the literature on the measurement of socioeconomic health inequalities by proposing a class of health inequality indices that address the issue of *blindness to health status*. We first show that any index that belongs to Wagstaff's class of health achievement indices or extended concentration indices may exhibit *blindness to health status*. To highlight the principle of health transfer, we construct a class of uni-dimensional indices of health inequality by borrowing the mathematical structure of Atkinson (1970) indices. We show that these Atkinsonian indices exhibit blindness to socioeconomic inequality but are sensitive to pure health inequality. We also compare both types of index. Finally, building on the well known rank dependent expected utility framework (Quiggin, 1982), we combine Wagstaff's class of health achievement (and extended health concentration) indices with our Atkinsonian health inequality indices and propose a general class of indices that overcomes *blindness to health status* and obeys the *principle of income-related health transfers*. Using Quiggin's (1982) allows us to preserve the well established properties of socioeconomic health inequality indices (rank dependence) and exploit the analogy between risk aversion in the expected utility framework and pure health inequality aversion (i.e. obeying the *principle of health transfers*) to introduce an arbitrage between health status and socioeconomic status.[4] We finally present an empirical illustration to provide evidence that this arbitrage may matter in practice and is not only a theoretical issue.

The remainder of the paper unfolds as follows. The next section presents the measurement framework on which our contribution will be based. In Section 3, we will introduce a new class of health achievement and inequality indices: the Atkinson-Wagstaff class of health achievement and health inequality indices. Section 4 presents a brief empirical illustration using the Joint Canada/United States Surveys of Health 2004 and the Canadian Community Health Survey 2007–2008. The last section summarizes our results.

2. Review of available measures

The main aim of this paper is to provide a measurement framework that overcomes *blindness to health status* by capturing pure and socioeconomic health inequalities simultaneously. To achieve this objective, we build on Quiggin (1982) and introduce an arbitrage between health status and socioeconomic status by combining two classes of indices: (a) Wagstaff health achievement and extended concentration indices and (b) Atkinson indices.

In what follows, we provide a description of the measurement framework of each of these indices. We first introduce Wagstaff's health achievement indices and extended concentration indices and discuss the possible issues that may result from the use of these indices by providing a numerical example. We then turn our attention to pure health inequality indices (i.e. Atkinsonian indices) as they are a necessary ingredient in the solution that we propose. We also discuss the well known problems associated with pure health inequality indices.

2.1. Wagstaff's health achievement indices and health concentration indices

The concentration index measures socioeconomic health inequality by ranking individuals according to their socioeconomic status (from lowest to highest) and then looking at the health distribution given this ranking. Let r_i, $i = 1$ to N, be the rank of individual i in a population of N individuals and h_i be the health status of individual i., then Wagstaff's achievement indices (Wagstaff, 2002) can be written as follows:

$$A(\nu) = \sum_{i=1}^{N} \theta(r_i;\nu)h_i, \tag{1}$$

where

$$\theta(r_i;\nu) = \frac{(N-r_i+1)^{\nu} - (N-r_i)^{\nu}}{N^{\nu}}, \ \nu \geq 1. \tag{2}$$

For simplicity, it is assumed that health status h_i is a ratio-scale variable but one could use categorical variables by applying the count transformation proposed in Makdissi and Yazbeck (2014). Following Yitzhaki (1983), ν in equation (2) can be interpreted as a parameter of aversion to socioeconomic health inequality.[5] If $\nu = 1$, there is no aversion to socioeconomic health inequality and $A(1)$ is simply the average health status, $\mu_h = \frac{1}{N}\sum_{i=1}^{N} h_i$. If $\nu > 1$, then the

[2] By *blindness to health status* we mean that these socioeconomic health inequality indices ignore the fact that, in some circumstances, a health transfer from a poorer person to a richer person (provided that the former is in much better health) increases social welfare.

[3] Erreygers et al. (2012) point to it again 6 years after Bleichrodt and van Doorslaer (2006) without providing a solution.

[4] Note that Erreygers (2013) dual Atkinson measure of socioeconomic inequality of health does not overcome this problem. Erreygers (2013) uses Atkinson's equally distributed equivalent health framework but does not use, as we do, the mathematical form of Atkinson's inequality indices. As noted by Erreygers (2013), given the bi-linear nature of his measure, the marginal impact of a change in health is the same regardless of the initial health status.

[5] Note that Yitzhaki (1983) considers the context of income inequality.

achievement index becomes averse to socioeconomic inequalities in health.

Wagstaff's class of extended concentration indices, $C(\nu)$, can be derived from achievement indices defined in (1) using the following relationship:

$$C(\nu) = 1 - \frac{A(\nu)}{\mu_h}. \tag{3}$$

When $\nu = 2$, equation (3) represents the standard health concentration index that is widely used in the health inequality literature.

As argued earlier, any index that belongs to Wagstaff's class of health achievement (concentration) indices increase (decrease) when a health transfer is made from an individual i at a lower rank in the health distribution to a person j at a higher rank (i.e. $h_i < h_j$), provided that the former has a slightly higher income (i.e. $r_i > r_j$). This is why we say they are *blind to health status*. To provide a clear illustration of this measurement issue, we consider a situation where a policy maker (who has to choose between two alternative policies) is faced with the hypothetical population of 5 individuals as represented in Table 1. In this example, it is assumed that individual health status, h_i, is a ratio-scale variable that takes value between 0 and 1 (one may think of it as a health-related quality of life index) where h^0 is health status before any policy intervention, h^1 is health status after implementing policy 1 and h^2 is health status after implementing policy 2. Assume that policy 1 can reallocate 0.01 unit of health from the individual at socioeconomic rank 4 who has a poor health status ($h_4^0 = 0.10$) to the individual at socioeconomic rank 2 who already has a good health status ($h_2^0 = 0.98$). The second policy, can reallocate the same 0.01 of a unit of health to the individual at socioeconomic rank 2 from the individual at socioeconomic rank 3 who has an initial health status of $h_3^0 = 0.88$.

Computing average health status (i.e., $A(1)$) before and after any of the two policy alternatives, yields the same value: $\mu_h^0 = \mu_h^1 = \mu_h^2 = 0.722$. However, computing the health achievement index $A(2)$ and the health concentration index $C(2)$ provide different rankings for these three scenarios. Health achievement and health concentration indices before and after the policy intervention are respectively $A_0(2) = 0.8164$ and $C_0(2) = -0.1307$ (before), $A_1(2) = 0.8180$ and $C_1(2) = -0.1330$ (after policy 1) and, $A_2(2) = 0.8172$ and $C_2(2) = -0.1319$ (after policy 2).[6] Results shown in this hypothetical numerical example suggest that if a policy maker's decision relies on health achievement indices and health concentration indices, then implementing any of these two policies leads to a social improvement. Furthermore, this example indicates that based on the information provided by the two indices, policy 1 is likely to be selected as the preferred policy if the objective a the policy maker is to maximize the value of the health achievement index or minimize the value of the concentration index. Such a conclusion is debatable as it is not clear that one would want to choose a policy that reallocates health resources by taking away from an individual who is in very poor health based on his relatively high socioeconomic status.

This numerical example raises two important questions: (1) why would Wagstaff health achievement indices and health concentration indices exhibit such behavior? (2) is this behavior observed in practice?

The answer to the first question resides in the structure of these indices as by construction they capture health inequality while relying exclusively on the socioeconomic ranks. More specifically, the impact of a marginal increase in the level of health status h_i on the achievement index $A(\nu)$ is independent of the original health status (i.e, before the hypothetical health transfer) and is decreasing in the socioeconomic rank r_i. This is why one has to be cautious when using such indices for health policy evaluation or population health monitoring as, in some cases, the results obtained may be based on contestable ethical values. To answer the second question, it is important to emphasize that in practice there is a lot of heterogeneity in health statuses by income ranks in survey data. There are many instances where we observe pairs of individuals where one has a better health status but lower socioeconomic status than the other. For instance, a preliminary investigation of the sample in Joint Canada/United States Surveys of Health 2004 [7] comparing the highest quintile with the lowest quintile, reveals a positive health/income gradient between the two groups (the average Health Utility Index Mark 3, HUI3, is 0.7892 in the low quintile and 0.9310 in the high quintile).[8] However, as depicted in Fig. 1, while the high income group has a more favorable HUI3 distribution, both densities overlap at many points. This suggests that having a pair of individuals such that one has a better health status but lower socioeconomic status than the other would not be an uncommon occurrence.

Given that the rank dependent structure of the concentration index may induce policy makers to contestable decision making, it is crucial that we introduce some arbitrage between socioeconomic health inequality and pure health inequality. In order to do so, we need to combine these two types of indices (i.e., exploit the properties of socioeconomic health inequality indices and pure health inequality indices). The most natural candidate that allows for the introduction of pure health inequality is the Gini index as it is mathematically akin to concentration indices. While both measures share a rank dependent structure, they differ in their ranking variable: the Gini index of health inequality uses ranks of individuals in the health distribution whereas the concentration index uses the socioeconomic ranks. As the combination of two different rank dependent indices based on different definitions of rank is not possible, we will rely on Atkinsonian type of indices (instead of the Gini). These indices have the advantage of measuring pure health inequality without necessarily being rank dependent. In fact, they capture pure health inequality by imposing a concave social evaluation function of health status.

2.2. Atkinsonian health achievement and pure health inequality indices

Atkinson's social welfare function is given by:

$$S^A(\varepsilon) = \begin{cases} \frac{1}{N}\sum_{i=1}^{N}\frac{h_i^{1-\varepsilon}}{1-\varepsilon} & \text{for } \varepsilon \neq 1 \\ \frac{1}{N}\sum_{i=1}^{N}\ln h_i & \text{for } \varepsilon = 1 \end{cases}, \tag{4}$$

where $\varepsilon \geq 0$ may be interpreted as a parameter of pure health inequality aversion. When $\varepsilon = 0$ then $S^A(0)$ is the average health status μ_h.

In the context of income inequality measurement, Atkinson (1970) adapts the certainty equivalent from economic theory of uncertainty and defines the equally distributed equivalent income.

[6] It is important to note that in our example, individuals located at the bottom of the socioeconomic distribution have higher health statuses.

[7] More details on the survey are offered in the empirical section.

[8] The interested reader can refer to the following link for details on HUI3: http://www.healthutilities.com/hui3.htm.

Table 1
Hypothetical population.

Socioeconomic rank	Initial health status h_i^0	Health status after policy 1 h_i^1	Health status after policy 2 h_i^2
1	0.90	0.90	0.90
2	0.98	0.99	0.99
3	0.88	0.88	0.87
4	0.10	0.09	0.10
5	0.75	0.75	0.75

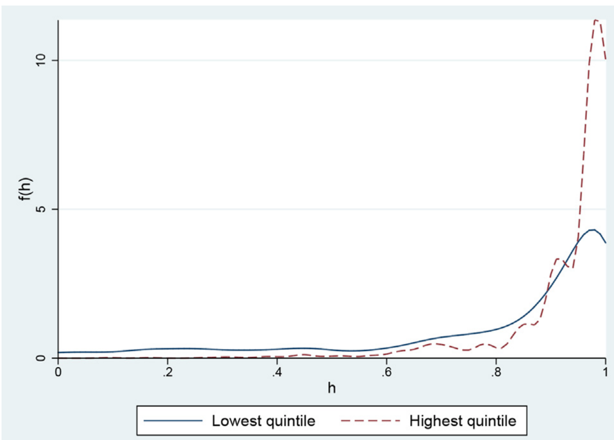

Fig. 1. Density of HUI3.

In the same spirit as Bleichrodt and van Doorslaer (2006) and Erreygers (2013), we define the equally distributed health status, $\xi^A(\varepsilon)$. This theoretical concept of equally distributed health status refers to the level of health such that, if everyone has this same level of health, the equal distribution of health lies on the same social indifference curve as the actual health distribution. We can interpret the equally distributed health status as the Atkinsonian pure health achievement index. Formally it is defined as:

$$\xi^A(\varepsilon) = \begin{cases} \left\{ \dfrac{1}{N} \sum_{i=1}^{N} h_i^{1-\varepsilon} \right\}^{\frac{1}{1-\varepsilon}} & \text{for } \varepsilon \neq 1 \\ \exp\left(\dfrac{1}{N} \sum_{i=1}^{N} \ln h_i \right) & \text{for } \varepsilon = 1 \end{cases} \tag{5}$$

The Atkinson index of pure health inequality $I^A(\varepsilon)$ associated with the Atkinsonian pure health achievement index, $\xi^A(\varepsilon)$, is defined as:

$$I^A(\varepsilon) = 1 - \frac{\xi^A(\varepsilon)}{\mu_h}. \tag{6}$$

Atkinsonian indices of pure health achievement and pure health inequality overlook (by construction) the socioeconomic dimension of health inequality. To illustrate this point, we compute the Atkinsonian health achievement index and the corresponding health inequality index using the two hypothetical populations in Table 2. The computed indices are, $\xi_A^A(1) = \xi_B^A(1) = 0.5662$ and $I_A^A(1) = I_B^A(1) = 0.2157$ as any Atkinsonian index would yield the same numerical values for these two populations. This is the case because Atkinsonian indices are by construction blind to the socioeconomic dimension of health inequality. As argued by Wagstaff et al. (1989) and Wagstaff et al. (1991), the analyst may be more interested in the socioeconomic dimension of health inequality than in pure health inequality. This is why they suggested the use of the health concentration index.

2.3. Comparing Wagstaff and Atkinson class of indices

In this section, we will use the numerical examples provided in the two earlier sections in order to compare Wagstaff and Atkinson class of indices.

If we consider the example in Table 3, the Atkinson indices indicate that policy 1 is not desirable since $\xi_0^A(1) = 0.5662$, $I_0^A(1) = 0.2157$, $\xi_1^A(1) = 0.5556$ and $I_1^A(1) = 0.2305$. While this conclusion is in contradiction with the one obtained using Wagstaff's class of indices, it appears as intuitive from an ethical perspective. Indeed, it is not appropriate to transfer health resources from someone who has a very poor health status to someone who is almost in perfect health (as would be suggested if we used a concentration index).

If we were to rely on Wagstaff's health achievement index $A(2)$ and the health concentration index $C(2)$ and revisit Table 2, the obtained results (as shown in Table 4) would indicate that the health distribution of population B is preferred to the health distribution of population A. This is the case because $A_B(2) = 0.8748 > A_A(2) = 0.5692$ and $C_B(2) = -0.2116 < C_A(2) = 0.2116$. These results are in contradiction with the results obtained when using Atkinson indices where $\xi_B^A(1) = \xi_A^A(1)$ and $I_B^A(1) = I_A^A(1)$.

This lack of congruence between the conclusions reached when using Atkinson indices and those reached when using Wagstaff indices arises for two reasons. First, Wagstaff health achievement indices and health concentration indices focus on the socioeconomic dimensions of health inequalities. Thus, they are by construction totally blind to pure health inequalities. Second, Atkinson indices focus on pure health inequality and are therefore by construction blind to socioeconomic status. The purpose of the next section will be to propose a class of indices that captures pure health inequality aversion in addition to socioeconomic health inequality aversion.

3. Atkinson-Wagstaff health achievement and health inequality indices

In this section, we build a class of indices that overcome *blindness to health status*. Following Erreygers (2013), we first describe the social welfare function underlying these indices. This has the advantage of highlighting the ethical preferences imbedded in the inequality indices. We then construct a class of indices displaying these preferences.

3.1. Welfare foundations

Assume that we have a population of N individuals, each individual i, $i = 1$ to N, has a vector α_i of K attributes affecting his individual wellbeing. Obvious examples of the such attributes are income, health and education. Following Harsanyi (1955), we assume that there is an impartial observer behind the veil of ignorance. This observer has to rank different joint distributions of attributes without knowing which one of the α_i will be his. To

Table 2
Two hypothetical populations.

Socioeconomic rank	Population *A* health statuses h_i^A	Population *B* health statuses h_i^B
1	0.10	0.98
2	0.75	0.90
3	0.88	0.88
4	0.90	0.75
5	0.98	0.10

formalize the social judgement underlying the existing and the proposed indices, we employ a set of axioms.

Axiom 1. *The observer has rank dependent expected utility preferences à la Quiggin.*

These preferences take the following form

$$W(\alpha_1, \alpha_2, \ldots, \alpha_N) = \frac{1}{N}\sum_{i=1}^{N}\theta(r_i)U(\alpha_i), \tag{7}$$

where r_i is the individual rank.

Axiom 2. *The socioeconomic rank is a function of only one attribute, income.*

Axiom 3. *$U(\alpha)$ is additively separable in the attributes.*

Debreu (1960) shows that Axiom 3 is a necessary and sufficient condition allowing for the analysis of the socioeconomic distribution of a single attribute such as health. It follows that the social welfare function has the following form:

$$W(\alpha_1, \alpha_2, \ldots, \alpha_N) = \frac{1}{N}\sum_{i=1}^{N}\theta(r_i)\sum_{j=1}^{K}u_j(\alpha_{ij}). \tag{8}$$

If for instance, we consider three attributes: income (y), health (h) and education (e) (i.e. $\alpha = (y,h,e)$), equation (8) becomes

$$W(y,h,e) = \frac{1}{N}\sum_{i=1}^{N}\theta(r_i)\left[u_y(y_i) + u_h(h_i) + u_e(e_i)\right]. \tag{9}$$

This separability assumption allows one to focus the analysis on the socioeconomic distribution of one single attribute, *ceteris paribus*.

We follow Fleurbaey (2006) and interpret an index of achievement in one attribute as the contribution of the socioeconomic distribution of this attribute to total wellbeing. This can be achieved by rewriting equation (8) as

$$W(\alpha_1, \alpha_2, \ldots, \alpha_N) = \sum_{j=1}^{K}w_j(\alpha_j), \tag{10}$$

where

$$w_j(\alpha_j) = \frac{1}{N}\sum_{i=1}^{N}\theta(r_i)u_j(\alpha_{ij}). \tag{11}$$

If the attribute of interest is health, then equation (11) becomes the health achievement and takes the following form

$$w_h(h) = \frac{1}{N}\sum_{i=1}^{N}\theta(r_i)u_h(h_i). \tag{12}$$

When focussing on equation (12) it is important to remember that both income and education levels still influence the global social welfare functions in (10). In other words, if everyone's income was to double the underlying social welfare function in (10) increases even if the health achievement index in (12) remains unchanged (because of separability).

Table 3
Hypothetical policies: Atkinson vs. Wagstaff.

Socioeconomic rank	Initial status	After policy 1	After policy 2
Achievement			
Atkinson $\xi^A(1)$	0.5662	0.5556	0.5661
Wagstaff $A(2)$	0.8164	0.8180	0.8172
Inequality			
Atkinson $I^A(1)$	0.2157	0.2305	0.2159
Wagstaff $C(2)$	−0.1307	−0.1330	−0.1319

Table 4
Two hypothetical populations: Atkinson vs. Wagstaff.

Index	Population *A*	Population *B*
Achievement		
Atkinson $\xi^A(1)$	0.5662	0.5662
Wagstaff $A(2)$	0.5692	0.8748
Inequality		
Atkinson $I^A(1)$	0.2157	0.2157
Wagstaff $C(2)$	0.2116	−0.2116

Axiom 4. ***Conditional principle of income-related health transfer***: *Transferring health from a rich person to a poorer person who has initially the same health does not decrease social welfare.*

The preferences underlying the social welfare function obey the *conditional principle of income-related health transfer* if the weight function $\theta(r_i)$ is non increasing in socioeconomic ranks (i.e. if $\theta'(r_i) \le 0$).

Axiom 5. ***Conditional principle of health transfer***: *A transfer of health from someone who is healthier to someone who has the same socioeconomic status but is less healthy does not decrease social welfare.*

The preferences underlying the social welfare function obey the *conditional principle of health transfer* if $u_h(h_i)$ is concave (i.e. $u_h'(h_i) \ge 0$ and $u_h''(h_i) \le 0$). At this point, it is important to mention that the implicit social welfare framework underlying the health concentration index (as well as Wagstaff (2002) classes of indices) imposes Axioms 1 to 4 and the linearity of the $u_h(h_i)$ function. In this paper, by imposing Axiom 5 instead of linearity, we allow for a more general setting that is anchored in an established ethical framework. More specifically, by imposing Axiom 5, our framework includes the health concentration and Wagstaff indices as particular cases.[9]

Before turning to the specific indices, it is important to highlight the differences between the welfare framework of Erreygers (2013)

[9] Note that $u_h''(h_i) = 0$ is a particular case of.$u_h''(h_i) \le 0$

and our framework. By imposing separability of $U(\alpha)$, our framework restricts the link between income and health through socioeconomic ranks (i.e. through the weight function). This differs from Erreygers (2013) who uses a general wellbeing function that depends on both intensity of income and health. While our assumption may seem more restrictive than Erreygers', it is a standard implicit assumption made in any pure or socioeconomic health inequality index. Erreygers (2013) does not make this assumption in his initial discussion of the social welfare function. However, he has to impose a linearity assumption (which is one particular form of separability) on his wellbeing function in order to get the properties that he considers desirable. Compared to our initial separability assumption, Erreygers' final assumption is more restrictive (i.e. restricts the utilities to be linear) and does not allow to overcome *blindness to health status*. Our separability assumption allows us to consider non linear $U(\alpha)$, which is an essential ingredient in overcoming *blindness to health status*. If one is not willing to make this separability assumption, it would not be theoretically possible to measure inequality in only one attribute (e.g. health). In Section 7.4 Erreygers (2013) suggests that one may introduce nonlinearity by allowing the social welfare function to be a function of two variables that are themselves concave functions of health and income. By doing this, the inequality index becomes an index of inequality in satisfaction or happiness, which beyond the scope of socioeconomic health inequality.

3.2. The Atkinson-Wagstaff class of indices

To implement empirically the general class of indices described in Section 3.1, we combine Wagstaff's weight function (i.e. imposing the conditional principle of income-related health transfer) to Atkinson's utility function (i.e. imposing the conditional principle of health transfer) and build a specific class of indices obeying all the axioms in Section 3.1. This class of indices is built on two parameters of inequality aversion: one parameter of aversion to socioeconomic health inequality and one parameter of aversion to pure health inequality. The main advantage of combining these two classes of indices is that widely used indices such as the health concentration index, Wagstaff health achievement indices and Atkinson indices become specific examples of this more general class. In doing so, this paper is related to the work of Araar and Duclos (2003) who propose a unidimensional Gini-Atkinson class of indices. While Araar and Duclos (2003) combined Gini and Atkinson indices in the context of measurement of income inequality, this paper proposes a novel approach as far as the dimensions of wellbeing considered. Unlike Araar and Duclos (2003), we rank in a dimension (i.e., income) different to that of the variable in which inequality is measured (i.e, health) and propose a "generalized" form of achievement and its corresponding version of health inequality indices.[10] This new "generalized" version of health achievement indices take the following form:

$$S(\nu,\varepsilon)=\begin{cases}\sum_{i=1}^{N}\theta(r_i;\nu)\dfrac{h_i^{1-\varepsilon}}{1-\varepsilon} & \text{for } \nu\geq 1,\ \varepsilon\geq 0 \text{ and } \varepsilon\neq 1\\ \sum_{i=1}^{N}\theta(r_i;\nu)\ln h_i & \text{for } \nu\geq 1,\ \varepsilon=1\end{cases} \tag{13}$$

where $\theta(r_i;\nu)$ is given by equation (2). The corresponding equally distributed health status is given by:

$$\xi(\nu,\varepsilon)=\begin{cases}\left\{\sum_{i=1}^{N}\theta(r_i;\nu)h_i^{1-\varepsilon}\right\}^{\frac{1}{1-\varepsilon}} & \text{for } \nu\geq 1,\ \varepsilon\geq 0 \text{ and } \varepsilon\neq 1\\ \exp\left(\sum_{i=1}^{N}\theta(r_i;\nu)\ln h_i\right) & \text{for } \nu\geq 1,\ \varepsilon=1\end{cases} \tag{14}$$

and the class of health inequality indices takes the following form:

$$I(\nu,\varepsilon)=1-\frac{\xi(\nu,\varepsilon)}{\mu_h}. \tag{15}$$

As mentioned earlier, we can interpret ν as a parameter of socioeconomic health inequality aversion (Yitzhaki, 1983), and we can interpret ε as a parameter of pure health inequality aversion (Atkinson, 1970). When ε is set to zero, we obtain Wagstaff's class of achievement and extended concentration indices. Further, when ε is set to zero and ν is set to two, then $I(2,0)$ is the widely used health concentration index. When ν is set to one, we obtain the Atkinsonian class of achievement and inequality indices. If $\nu\neq 1$ and $\varepsilon\neq 0$, the index displays aversion to both pure and socioeconomic health inequality. An analyst or policy maker who wishes to account for health status and socioeconomic status simultaneously, should choose a positive value for ε and a value for ν that exceeds one.

At this point, one may wonder for what value of ε the policy maker would value a transfer of health from an individual i with better health to another person j in poorer health ($h_j < h_i$) but higher socioeconomic rank ($r_j > r_i$). From equation (13), we can find the marginal contribution of the health status of individual i:

$$\frac{\partial S(\nu,\varepsilon)}{\partial h_i}=\frac{(N-r_i+1)^{\nu}-(N-r_i)^{\nu}}{N^{\nu}}h_i^{-\varepsilon}. \tag{16}$$

From equation (16), one can find a critical value of ε such that the policy maker would favor this health transfer:

$$\varepsilon\geq\frac{\ln\left[(N-r_i+1)^{\nu}-(N-r_i)^{\nu}\right]-\ln\left[(N-r_j+1)^{\nu}-(N-r_j)^{\nu}\right]}{\ln h_i-\ln h_j}. \tag{17}$$

Inspection of equation (17) indicates that this critical value of aversion to pure health inequality will be contingent on the distance of the two socioeconomic ranks, r_i and r_j, the level of aversion to socioeconomic health inequality, ν, and the difference between health statuses, h_i and h_j.

Using the new class of indices we revisit the hypothetical scenarios provided in section 2. If we consider the example provided in Table 2 and compute the proposed Atkinson-Wagstaff indices then we obtain: $\xi_A(2,1)=0.3873$, $I_A(2,1)=0.4635$, (for distribution A) and $\xi_B(2,1)=0.8278$, $I_B(2,1)=-0.1466$ (for distribution B). Given these results, one can say that population B displays higher health achievement and lower health inequality than population A. Comparing these results with the ones obtained in Table 4 one can notice that results obtained from the Atkinson class of indices showed that distributions in population A and population B were similar, whereas Wagstaff class of indices revealed that distribution in population B was preferred. Thus, this example shows how the socioeconomic dimension of health inequality that is unaccounted for in an Atkinson index is now captured.

Table 5 presents the Atkinson-Wagstaff indices computed using information on the two hypothetical policies provided in Table 1. It is clear that the rankings of the two policies are different from the ranking obtained by the Wagstaff and the Atkinsonian indices presented earlier in Table 3. Following the implementation of the

[10] Note that Araar and Duclos consider a special case of Berrebi and Silber (1981). Lambert and Zheng (2011) have considered this latter class of indices in the measurement of pure health inequality.

Table 5
Hypothetical policies: Atkinson-Wagstaff indices.

Socioeconomic rank	Initial status	After policy 1	After policy 2
Achievement			
$\xi(2,1)$	0.6998	0.6930	0.7002
Inequality			
$I(2,1)$	0.0308	0.0402	0.0302

Table 6
Indices for Canada and the U.S.A.

	$\xi(\nu,\varepsilon=1)$			$I(\nu,\varepsilon=1)$		
	$\nu=1$	$\nu=2$	$\nu=3$	$\nu=1$	$\nu=2$	$\nu=3$
Canada	0.810074	0.759429	0.729261	0.071116	0.129189	0.163782
USA	0.789987	0.725244	0.683903	0.084625	0.159644	0.207547
	$\xi(\nu=2,\varepsilon)$			$I(\nu=2,\varepsilon)$		
	$\varepsilon=0$	$\varepsilon=1$	$\varepsilon=2$	$\varepsilon=0$	$\varepsilon=1$	$\varepsilon=2$
Canada	0.841327	0.759429	0.349726	0.03528	0.129189	0.598981
USA	0.825597	0.725244	0.284505	0.043362	0.159644	0.670338

first policy, health achievement decreases and health inequality increases. This ranking of policy 1 is compatible with the Atkinsonian ranking. After policy 2, health achievement increases and health inequality decreases. This ranking is compatible with the Wagstaff ranking. The numerical examples discussed above show that Wagstaff-Atkinson indices allow us to introduce an arbitrage between socioeconomic status and health status, as they account for both pure and socioeconomic health inequality aversion. It is important to note that this new index is constructed so that it reacts favorably to a redistribution from an individual with a slightly lower health (i.e., when the difference in health status is small) but higher socioeconomic status to another with a *slightly* better health but lower socioeconomic status (i.e., from individual at socioeconomic rank 3 to individual at socioeconomic rank 2). However, if the difference in health status is large (e.g., individual at socioeconomic rank 4 compared individual at socioeconomic rank 2), the index reacts negatively to a similar transfer even if the individual with the poor health status has a higher socioeconomic status. As such, the index exhibits an arbitrage between socioeconomic rank and health.

4. Empirical illustration

In this section, we present a brief illustration using the parametric class of indices introduced in the previous section. We provide empirical evidence that this parametric class may, in some cases, rank distributions differently when compared to rankings given by Wagstaff and Atkinsonian classes of indices separately. In a first step, we will compare health inequalities between the U.S. and Canada. We show how the health achievement and the health inequality rankings between Canada and the U.S. seem robust to a change in socioeconomic or pure health inequality aversion. In a second step, we focus on health inequalities within Canada, more precisely in the Greater Montréal region, and divide the extended Montréal region into four administrative subregions. This allows us to illustrate how a change in socioeconomic and/or pure health inequality aversion can change the ranking between some of these subregions once the indices' *blindness to health status* is accounted for.

4.1. Comparing health distribution in the U.S. and Canada

To compare health achievement and health inequality in Canada and in the U.S., we use the Joint Canada/United States Surveys of Health (JCUSH) 2004. This survey entails 8688 observations of which 3505 are Canadian residents and 5183 are U.S. residents. It covers individuals between the age of 18 and 85 years and information about their clinical condition as well as their demographic characteristics and their socioeconomic status. We use information on household income to infer the socioeconomic rank of individuals. In this paper, an individual health status is measured by the Health Utility Index Mark 3 (HUI3), which covers eight attributes: vision, hearing, speech, ambulation, dexterity, emotion, cognition, and pain. Each attribute has five or six levels and each attribute utility score ranges from 0 (for instance blind for vision) to 1 (perfect vision). The HUI3 ranges from −0.36 to 1, the negative values are there to express a state that is worse than death whereas values of 0 reflect death.

Looking at Table 6 we notice that Canada has higher health achievement indices and lower health inequality indices and that these results are robust to all assigned values of ν and ε. More specifically, these rankings are all similar to Wagstaff's achievement index $\xi(2,0)$ and to the standard health concentration index $I(2,0)$.[11] This means that, in this particular case, all the estimated indices would have ranked Canada above the U.S regardless of whether they are *blind to health status*. Thus, at this point, the added value of using our class of indices remains mainly theoretical as it is not yet empirically verified. While one might be inclined to ignore this issue, we will show through the next illustration that *blindness to health status* can in fact occur and could contradict policy makers preferences.

4.2. Comparing health distribution within the Greater Montréal region

We next concentrate on health achievement and inequality within the Greater Montréal region in Canada and use the Canadian Community Health Survey (CCHS) 2007–2008. This survey is cross-sectional, it covers 131,061 Canadians aged 12 and above. It provides information related to their health status, their clinical conditions, their health care utilization as well as health determinants. We have 8572 observations for the Greater Montréal region. As in the previous example, we use information on household income to infer the socioeconomic rank of the individual and the HUI3 as indicator of the individual health status. Four subregions are considered: Montréal (located on an island in the St-Lawrence river), Laval (located on an island adjacent to Montréal), Montérégie (suburbs located on the south shore of the river) and Laurentides (suburbs located on its north shore).

The computed health achievement and inequality indices reported in Table 7 indicate the health achievement and health inequality rankings for the Greater Montréal region varies when different values of pure and socioeconomic health aversion parameters are considered. Let us focus on the upper panel of Table 7 and start by looking at the health inequality index, $I(1,1)$. When $\nu=1$, there is no socioeconomic health inequality aversion. We are therefore looking at Atkinsonian indices. The corresponding inequality ranking is: Laval, Montérégie, Laurentides and Montréal. If we introduce socioeconomic health inequality aversion (i.e. we set $\nu>1$), the inequality ranking for this particular example remains unchanged. As for the health achievement index, imposing no socioeconomic health inequality aversion, $\xi(1,1)$, results in the following ranking: Laval, Laurentides, Montérégie and Montréal.

[11] We take the case where $\nu=2$ since it is associated with the standard health concentration index. We acknowledge that Wagstaff's class of indices allows for ν to take any value larger than one.

Table 7
Indices for the Greater Montréal region.

	$\xi(\nu, \varepsilon = 1)$			$I(\nu, \varepsilon = 1)$		
	$\nu = 1$	$\nu = 2$	$\nu = 3$	$\nu = 1$	$\nu = 2$	$\nu = 3$
Montréal	0.834493	0.796713	0.775435	0.058153	0.100793	0.124808
Montérégie	0.846776	0.810485	0.7902	0.048085	0.088882	0.111686
Laval	0.851641	0.819217	0.80155	0.045213	0.081564	0.10137
Laurentides	0.850999	0.812145	0.789155	0.04811	0.09157	0.117285
	$\xi(\nu = 2, \varepsilon)$			$I(\nu = 2, \varepsilon)$		
	$\varepsilon = 0$	$\varepsilon = 1$	$\varepsilon = 2$	$\varepsilon = 0$	$\varepsilon = 1$	$\varepsilon = 2$
Montréal	0.866472	0.796713	0.37618	0.022059	0.100793	0.575426
Montérégie	0.867005	0.810485	0.486994	0.025344	0.088882	0.452539
Laval	0.873196	0.819217	0.49288	0.021047	0.081564	0.447425
Laurentides	0.869551	0.812145	0.309894	0.027358	0.09157	0.653367

Increasing ν to 2 does not change this ranking. However, increasing socioeconomic health inequality parameter ν to 3 changes the ranking to: Laval, Montérégie, Laurentides and Montréal. While these results may suggest ranking inconsistency, they are in line with Wagstaff's (2002) argument. Indeed, accounting for average health status and changing the level of socioeconomic health inequality aversion can modify rankings provided by a health inequality index.

Considering the lower panel of the table, it is important to keep in mind that when $\varepsilon = 0$, we have the Wagstaff class of health achievement and health concentration indices (i.e., no aversion to pure health inequality). Once we introduce pure health inequality aversion (i.e., $\varepsilon > 0$) and compute indices *à la* Atkinson-Wagstaff, it is clear that rankings provided by $\xi(2, \varepsilon = 0)$ and $I(2, \varepsilon = 0)$ change in most of the cases. This change reflects the impact of accounting for pure health inequality aversion when analyzing socioeconomic health inequalities. In this specific empirical example, we provide support for the relevance of our theoretical argument and show that it goes beyond the hypothetical example provided earlier. More specifically, if we consider health inequality indices $I(2, \varepsilon)$ and analyze how the rankings produced by these indices change with a variation of the parameter ε, then, for $\varepsilon = 0$, the subregions are ranked as follows (from lowest to highest inequality): Laval, Montréal, Montérégie and Laurentides. Note that for this ranking, only socioeconomic health inequality aversion is taken into account since the decision maker has no pure health inequality aversion (i.e. $\varepsilon = 0$). If we introduce pure health inequality aversion by increasing ε to 1, the ranking changes to: Laval, Montérégie, Laurentides and Montréal. Further, increasing pure health inequality to $\varepsilon = 2$ changes the ranking to: Laval, Montérégie, Montréal and Laurentides. As for the health achievement indices, if we consider the case where there are no pure health inequality aversion, $\xi(2, \varepsilon = 0)$, the ranking (from highest to lowest achievement) is: Laval, Laurentides, Montérégie and Montréal. The ranking stays the same when we increase ε to 1 but changes to: Laval, Montérégie, Montréal and Laurentides, when we consider $\varepsilon = 2$. The variation in rankings resulting from the use of different values for ε provides, once again, an empirical evidence of the indices' *blindness to health status* and thus highlights the relevance of the theoretical argument and the importance of addressing this measurement issue.

5. Conclusion

In this paper, we point out that socioeconomic health inequality indices may exhibit *blindness to health status*. In this case, contestable information of a policy's impact on socioeconomic health inequalities may emerge. Given that socioeconomic health inequality indices have a rank dependent structure (the sorting variable is the socioeconomic rank), the information arising from the rank in the health distribution is usually muted allowing thus for *blindness to health status* to occur. To introduce the information obtained from the rank in the health distribution in the Wagstaff class of indices, we propose a new class of indices that combines Wagstaff and Atkinson indices. This new class of indices accounts for *blindness to health status* by allowing for dependence between health status and socioeconomic rank to be present in the underlying social welfare function. To illustrate how the proposed class of indices may produce rankings that are different from those obtained by a standard Wagstaff class of achievement and inequality indices, we provide two empirical illustrations. In the first illustration, our proposed class of indices and Wagstaff class of achievement and inequality indices provide consistent rankings. However, in the second illustration the results obtained show that accounting for *blindness to health status* may change the rankings of health distributions. Our empirical illustration seems to corroborate our theoretical argument regarding the indices *blindness to health status*. As a result it highlights the importance of using the proposed class of indices when measuring socioeconomic health inequalities in policy evaluation. It is important to note that the proposed class reacts favorably to a redistribution from an individual with a slightly lower health but higher socioeconomic status to another with a slightly better health but lower socioeconomic status. However, if the difference in health status is large, the index will react negatively to a similar transfer even if the person with the lower health status has a high socioeconomic status. Given that the consequences of the indices *blindness to health status* are more important when there are large differences in health status, the proposed method accounts for those large and small differences by introducing an arbitrage between socioeconomic rank and health.

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