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A social-psychological reconstruction of Amartya Sen's measures of inequality and social welfare

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Abstract

The Gini coefficient features prominently in Amartya Sen's 1973 and 1997 seminal work on income inequality and social welfare. We construct the Gini coefficient from social-psychological building blocks, reformulating it as a ratio between a measure of social stress and aggregate income. We determine when as a consequence of an income gain by an individual, an increase in the social stress measure dominates a concurrent increase in the aggregate income, such that the magnitude of the Gini coefficient increases. By integrating our approach to the construction of the Gini coefficient with Sen's social welfare function, we are able to endow the function with a social-psychological underpinning, showing that this function, too, is a composite of a measure of social stress and aggregate income. We reveal a dual role played by aggregate income as a booster of social welfare in Sen's social welfare function. Quite surprisingly, we find that a marginal increase of income for any individual, regardless of the position of the individual in the hierarchy of incomes, improves welfare as measured by Sen's social welfare function.

Keywords: Measuring inequality; A social-psychological approach to the construction of the Gini coefficient; Properties of the reconstructed Gini coefficient; Sen's social welfare function; Sen's social welfare function as a composite of a measure of social stress and aggregate income

JEL classification: C43; D01; D31; D63; I31; P46

1. Introduction

In "On Economic Inequality" (1973 and 1997), Amartya Sen presented a formula of the Gini coefficient of inequality that has subsequently served as a standard representation of the coefficient. Drawing on that formula, in his book Sen proposed to measure social welfare as income per capita times one minus the Gini coefficient, arguing that in assessing wellbeing, income per capita alone is not a helpful guide.[1]

In this paper we modify Sen's presentation of the Gini coefficient. We do this by assembling the coefficient from social-psychological components. This construction enables us to provide a rationale for Sen's incorporation of the Gini coefficient in his measure of social welfare. Sen did not justify the choice of the Gini coefficient as the term in his social welfare function that stands for inequality. In "defense" of the function, Sen (1997, p. 137) remarked that "its interpretation as the mean income modified downward by the Gini inequality adds to its attraction as an intuitive and usable welfare indicator." For sure, this praise does not amount to a persuasive justification. Let alone that income inequality can be measured in a variety of ways of which the Gini coefficient is just one.

In 1912, Corrado Gini constructed an index, "the Gini coefficient," that turned out to be a widely used measure of inequality.[2] In spite of being not only a statistician but also a sociologist and a demographer, Gini developed his mathematical formula for measuring dispersion independently of social-psychological principles and preferences.

Here we construct the Gini coefficient from social-psychological building blocks. Dressing the coefficient in social-psychological clothes enables us to show that the coefficient has properties that up until now were not acknowledged. We integrate our approach to the construction of the Gini coefficient with Sen's social welfare function. This application not only endows the function with a social-psychological underpinning; it uncovers a dual role played by the population's aggregate income as a booster of social welfare, and it enables us to show that *any marginal increase in income improves welfare as measured by Sen's social welfare function*, the effect of such an increase on the Gini coefficient notwithstanding - even if it amounts to increasing income inequality as measured by the coefficient. This result,

[1] This functional form was first displayed in Sen (1976). It was subsequently reprinted in Sen (1982).
[2] "[T]he Gini coefficient [is] still the most commonly used measure of inequality in empirical work." (Sen, 1973, p. 149).

stated and proved in Claim 2, is powerful and surprising. A judgment as to whether from a social welfare point of view a marginal change in some income is warranted has to be based on an underlying social welfare function. Intuition has it that when this function is "sympathetic" to increases in income and "antipathetic" to increases in inequality, there are bound to be marginal increases in income that a social welfare criterion will deem unwarranted. When the basis for making a judgment is the social welfare function formulated by Sen, then the said intuition breaks down. This observation has far-reaching consequences for a wide spectrum of policies, ranging from the promotion of economic growth that affects incomes unevenly to the design and rationale of tax schemes.

Suppose that the manner in which a given income is distributed in a population affects people's stress, such that when the given income is distributed perfectly equally, the level of stress is minimal; when the given income is distributed perfectly unequally (one person receives all the income), the level of stress is maximal; when the extent of inequality is in-between, the level of stress is in-between; and the farther we are from perfect equality and the closer we are to perfect inequality, the higher the level of stress. What prompts this list of requirements is the notion that populations constitute social environments in which people compare what they have, including income, with what others have; that, in particular, people compare their incomes with the incomes of other people who are positioned on their right in the income distribution; and that unfavorable comparisons cause dismay. We refer to the stress or dismay as social, and as relative: social, because it arises from comparisons with others in people's social space; and relative, because even when people have a good income, they can experience stress or dismay when others, with whose incomes they compare theirs, have incomes that are even higher.

Indeed, in disciplines ranging from economics and psychology to public health and even to neuroscience (Zink et al., 2008), there is widespread recognition that comparisons with others significantly affect wellbeing. In particular, studies have shown that on a variety of health-related dimensions, people are stressed when they lag behind in comparison with their comparators. High levels of relative deprivation (low levels of relative income) were found to constitute a significant explanatory factor of adverse health outcomes such as suicide (Daly et al., 2013; Pak and Choung, 2020), death (Eibner and Evans, 2005), and mental ailments (Jones and Wildman, 2008; Layte, 2012). Reviews of evidence for the relationship between unequal income distributions and health outcomes are provided by Subramanian and

Kawachi (2004) and Pickett and Wilkinson (2015). The stress caused by low social status is often perceived as an intermediate factor linking the experience of relative deprivation with poor health outcomes (Wilkinson, 1997; Eibner and Evans, 2005; Cundiff et al., 2020). Delhey and Dragolov (2014) and others label this stress as "status anxiety." In this paper we refer to the stress discussed in this paragraph as social-psychological stress or as stress caused by relative deprivation.

2. Calibrating social stress

In population $N = \{1, 2, \ldots, n\}$, $n \geq 2$, let $y = (y_1, ..., y_n)$ be the vector of incomes of the members of the population. Let these incomes be ordered, $0 < y_1 < y_2 < \ldots < y_n$. RD_i - by which we denote the relative dismay (the income-related social stress) or the relative deprivation of individual i, $i = 1, 2, ..., n-1$, whose income is y_i - is defined as

$$RD_i \equiv \frac{1}{n} \sum_{j=i+1}^{n} (y_j - y_i), \tag{1}$$

where it is understood that $RD_n \equiv 0$.

The idea here is to aggregate the income excesses (the differences between the incomes that are higher than the income of individual i and the income of individual i) and normalize this sum, dividing it by the size of the population. A detailed derivation of this representation of an individual's relative deprivation is in Appendix A. This appendix is accompanied by Appendix B in which we present a brief historical account of the "adoption" of the sociological-psychological concept of relative deprivation by the discipline of economics.

By definition and construction, the concept of relative deprivation is the dual of the concept of reference group or comparison group. There is substantial literature on this topic, spanning from Stouffer et al. (1949) through Akerlof (1997) and all the way to our own recent writings, for example, Stark et al., (2017), Stark et al. (2018 a), Stark et al. (2018 b), Stark and Budzinski (2019), Stark et al. (2019 a), and Stark et al. (2019 b). The cited studies include deliberations and discussions on the identity of the reference group, and they provide many references to related works. For the purpose of the current paper, the reference group consists of the people or subjects whose income distribution and social welfare are of concern to the social planner, or put differently, of the people who come "under the jurisdiction" of the social planner. The incomes are known to these people as well as to the social planner, otherwise people's income distribution and the social welfare function that incorporates that distribution will not be amenable to policy intervention by the social planner.[3]

We denote the sum or the aggregate of the levels of RD_i in the population by *TRD* (*T* for total, *R* for relative, *D* for dismay or for deprivation):

$$TRD \equiv \frac{1}{n}\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}(y_j - y_i)\,. \tag{2}$$

3. Modifying Sen's presentation of the Gini coefficient

Once again, in population $N=\{1,2,\ldots,n\}$, $n \geq 2$, let $y=(y_1,...,y_n)$ be the vector of incomes of the members of the population, and let these incomes be ordered, $0 < y_1 < y_2 < \ldots < y_n$. Starting from Sen (1973), the Gini coefficient has been presented as

$$G \equiv \frac{\sum_{j=1}^{n}\sum_{i=1}^{n}\left|y_i - y_j\right|}{2n^2\overline{y}}, \tag{3}$$

where $\overline{y}=(1/n)\sum_{i=1}^{n} y_i$ is the population's average income.[4]

On noting that $\sum_{j=1}^{n}\sum_{i=1}^{n}\left|y_i - y_j\right| = 2\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}(y_j - y_i)$, an equivalent representation of *G* in (3), which disposes of the need to operate with absolute values, is

$$G = \frac{\frac{1}{n}\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}(y_j - y_i)}{\sum_{i=1}^{n} y_i} = \frac{TRD}{TI}, \tag{4}$$

[3] As we note in Section 5, calculating the level of relative deprivation as per the formula in (1) does not require that the individual concerned knows the incomes of all the individuals in his comparison group. Rather, what is needed is that the individual concerned knows the average income of the individuals in his comparison group who are positioned higher up in the income hierarchy.

[4] Ceriani and Verme (2012) present an illuminating account of the thinking that led Corrado Gini to formulate his index.

so the Gini coefficient in (4) is a ratio: *TRD* as defined in (2), divided by aggregate (total) income $\sum_{i=1}^{n} y_i = TI$.

Remark 1. Consider two income distributions: {1,4} and {2,5}. Although there is no difference between the values of the numerator of G in (4) in these two cases, G itself is smaller for {2,5} than for {1,4}, and for quite an interesting reason: eliminating relative deprivation in the case of {2,5}, and thereby reducing *G* to zero, will result in higher average income than eliminating relative deprivation in the case of {1,4}.[5] Holding other things equal, if we would prefer the Gini coefficient to "favor" higher average income over lower average income, namely if we would prefer that G for {2,5} will be lower than G for {1,4}, then this is what we will observe. Putting it somewhat differently: in computing the Gini coefficient, relative deprivation and aggregate income enter in opposite manners: for a given magnitude of relative deprivation, a higher aggregate income results in a lower Gini coefficient. The Gini coefficient for 1 and 2 is approximately 66 times bigger than the Gini coefficient for 99 and 100. It turns out then that if we want rich people to be bothered less by a given income discrepancy than poor people, then the Gini coefficient exhibits this sensitivity.

Remark 2. While relative deprivation and aggregate income influence the magnitude of the Gini coefficient in opposite directions, in the two-person cases such as the one in Remark 1, the impact of the relative deprivation term dominates. For example, when income distribution {1,4} is replaced by income distribution {1,5}, *TRD* goes up (by 1/3), which itself increases the magnitude of the Gini coefficient; aggregate income goes up (by 1/5), which itself decreases the magnitude of the Gini coefficient. The net outcome is that the Gini coefficient increases (by 1/9).[6] In fact, when the top income in any income distribution increases, *TRD* goes up, which itself increases the magnitude of the Gini coefficient; aggregate income goes up, which itself decreases the magnitude of the Gini coefficient; and yet the net outcome is that the Gini coefficient increases; the *TRD* effect dominates.[7]

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[5] When one income is two and a half times bigger than another income, we would expect a measure of inequality to record a lower magnitude than when one income is four times bigger than another income. However, here we single out for interpretation a different characterization.

[6] When the two incomes are *y* and *x*, such that $y > x$, $G = \frac{1}{2}\frac{y-x}{y+x}$ and $\frac{dG}{dy} = \frac{x}{(y+x)^2} > 0$.

[7] The two-person case is also revealing when both incomes increase. When percentage-wise the higher income increases by more than the lower income, then the *TRD* effect is stronger than the aggregate income effect, and the Gini coefficient increases.

Remark 3. In cases that involve more than two individuals, we get from (2) that for individual $k = 1, 2, ..., n$ whose income is y_k,

$$\frac{dTRD}{dy_k} = \frac{(k-1)-(n-k)}{n} = \frac{2k-1-n}{n}. \tag{5}$$

Namely a marginal increase of the income of individual *k* changes *TRD* by $\frac{2k-1-n}{n}$.[8] The reason for having the term $2k-1-n$ in the numerator of (5) is that individual *k* inflicts relative deprivation on $k-1$ individuals who are on his left in the income distribution, and is subject to relative deprivation inflicted on him by $n-k$ individuals who are on his right in the income distribution. Thus, in the *TRD* calculation, the income of individual *k* appears $(k-1)+[-(n-k)] = 2k-1-n$ times. (We note that in the construction of *TRD*, income y_k does not enter the formulas of the relative deprivation of individuals $k+1, k+2, \ldots, n$.)

As in Remark 2, we ask when an increase in *TRD* will dominate a concurrent increase in total income such that the magnitude of the Gini coefficient will "succumb to the power" of its *TRD* numerator rather than to the "force" of its *TI* denominator. In order to respond to this question, we first formulate a condition under which upon a marginal increase of the income y_k of individual *k*, *TRD* will increase. Clearly, for $2k-1-n \geq 0$, which is the same as $k \geq \frac{n+1}{2}$, it follows from (5) that $\frac{dTRD}{dy_k} \geq 0$. This is an interesting result in its own right: a rank-preserving rise in an income in the upper half of the income distribution increases the aggregate relative deprivation of a population. (And by the same token, a rank-preserving rise in an income in the lower half of the income distribution decreases the aggregate relative deprivation of a population.)

We will now analyze the effect of a marginal increase in income y_k of individual *k* on the Gini coefficient exhibited in (4). To begin with, we note that from (4) and (5),

$$\frac{dG}{dy_k} = \frac{\frac{2k-1-n}{n} TI - TRD}{(TI)^2} \tag{6}$$

[8] When $k = n$, the right-most term of (5) reduces to $\frac{n-1}{n}$.

which implies that $\frac{dG}{dy_k} > 0$ if $\frac{2k-1-n}{n}TI - TRD > 0$. We next formulate and prove a claim which reveals that there is an individual, k, such that a marginal increase of the income of individual *k* or of the income of any individual who is positioned to the right of individual *k* in the income distribution will result in the *TRD* effect dominating the *TI* effect. Consequently, the Gini coefficient will increase. The intuition behind this result follows from the latter part of Remark 2: we search for such a *k* in the upper part of the income distribution.

Claim 1. There exists a $k \in \left\{ \left\lfloor \frac{n+1}{2} \right\rfloor + 1, \dots, n \right\}$ (we refer to this *k* as the "pivotal *k*") such that for any $i \geq k$, a marginal increase of TRD will dominate the concurrent marginal increase of *TI*, causing the Gini coefficient to increase. Namely for $i \geq k$: $\frac{dTRD}{dy_i} > 0$; $\frac{dTI}{dy_i} > 0$; *and* $\frac{dG}{dy_i} = \frac{d\frac{TRD}{TI}}{dy_i} > 0$.

Proof. The proof proceeds in two steps. First, we formulate conditions under which $\frac{dTRD}{dy_i} > 0$ and $\frac{dTI}{dy_i} > 0$ hold. Taking this step enables us to narrow the domain over which to search for the pivotal *k*. Second, we investigate (6) as a function of *k*, with the aim of ascertaining that there exists a unique point at which there is a sign change of (6) from negative to positive.

From (5) we know that for $k > \frac{n+1}{2}$, $\frac{dTRD}{dy_k} > 0$. Also, for any $k = 1, 2, ..., n$, $\frac{dTI}{dy_k} = 1 > 0$. Noting that k is an integer, we therefore confine our search for the pivotal *k* to the domain $k \in \left\{ \left\lfloor \frac{n+1}{2} \right\rfloor + 1, \dots, n \right\}$.

Because, as already noted, from (6) it follows that $\frac{dG}{dy_i}$ is positive if the term $\frac{2k-1-n}{n}TI-TRD$ is positive, we inspect this term, expressing it as a function $D(k)=\frac{2k-1-n}{n}TI-TRD$ for $k=1,2,...,n$. Three properties of $D(k)$ are of interest:

(i) $D\left(\left\lfloor \frac{n+1}{2} \right\rfloor\right)<0$;

(ii) $D(n)>0$;

(iii) $D(k)$ monotonically increases with respect to *k*.

Taken together, (i), (ii), and (iii) imply that there exists a unique $k\in\left\{\left\lfloor \frac{n+1}{2} \right\rfloor+1,\ldots,n\right\}$ such that $D(i)>0$ for all $i\geq k$ and $D(i)\leq 0$ for $i<k$.[9] For $i\in\{k,k+1,\ldots,n\}$, $\frac{dTRD}{dy_i}>0$ and $\frac{dTI}{dy_i}>0$, inequalities that we know hold because $\{k,k+1,\ldots,n\}$ is a subset of the domain $\left\{\left\lfloor \frac{n+1}{2} \right\rfloor+1,\ldots,n\right\}$, and for this domain we have already established that these two inequalities hold.

What remains to complete the proof is to show that properties (i), (ii), and (iii) indeed hold.

Property (i) holds because $D\left(\left\lfloor \frac{n+1}{2} \right\rfloor\right)=\frac{2\left\lfloor \frac{n+1}{2} \right\rfloor-1-n}{n}TI-TRD\leq -TRD<0$.

To understand why property (ii) holds, we first note that $D(n)=\frac{2n-1-n}{n}TI-TRD=\frac{n-1}{n}TI-TRD$. To show that $\frac{n-1}{n}TI-TRD$ is positive, we recall that in Remark 3 we noted that in calculating *TRD*, individual *k* whose income is y_k

[9] We note that because k is a discrete variable, it could be the case that $D(k)>0$ will hold only for $k=n$.

appears $2k-1-n$ times. Summing over all the individuals, $k=1,2,...,n$, we can exploit this feature and express TRD in a different form than in (2):

$$TRD = \sum_{k=1}^{n} \frac{2k-1-n}{n} y_k .$$

Because for $k=n$ we get that $\frac{2k-1-n}{n} = \frac{n-1}{n}$, and because for $k=n-1$ we get that $\frac{2k-1-n}{n} = \frac{n-3}{n}$, we can establish that

$$\begin{aligned} TRD &= \sum_{k=1}^{n} \frac{2k-1-n}{n} y_k = \frac{n-1}{n} y_n + \sum_{k=1}^{n-1} \frac{2k-1-n}{n} y_k \\ &< \frac{n-1}{n} y_n + \sum_{k=1}^{n-1} \frac{n-3}{n} y_k = \frac{n-1}{n} y_n + \frac{n-3}{n} \sum_{k=1}^{n-1} y_k < \frac{n-1}{n} y_n + \frac{n-1}{n} \sum_{k=1}^{n-1} y_k = \frac{n-1}{n} TI. \end{aligned}$$

Namely $TRD < TI$. From the result $TRD < \frac{n-1}{n} TI$ it follows that $D(n) = \frac{n-1}{n} TI - TRD > 0$ holds.

Finally, that property (iii) holds follows directly from the definition of $D(k) = \frac{2k-1-n}{n} TI - TRD$ upon noting that TI and TRD in this expression do not depend on k, so that a higher k translates into a higher $D(k)$. Q.E.D.

The significance of Claim 1 is that by defining a line of demarcation, the claim settles a tension. The tension arises when a gain from higher income is accompanied by pain from higher relative deprivation. The claim responds to the associated "dilemma of the Gini coefficient" by dividing a given income distribution into two mutually exclusive and jointly exhaustive domains such that the effects of an increase in income in each of the two domains are the opposite of each other. In the hypothetical case in which inequality is all that matters to a policy maker, the claim provides a precisely defined guide.

An example. It is revealing to consider the specific case of an income distribution in which incomes are equally spaced, and in which $y_i = i$. Drawing on the discussion in Remarks 2 and 3, the range over which we should search for the "pivotal" income is the upper half of the income distribution. In the considered specific case, it holds that

$$TRD=\frac{1}{n}\sum_{i=1}^{n-1}\sum_{k=1}^{i}k=\frac{1}{n}\sum_{i=1}^{n-1}\frac{(i+1)i}{2}=\frac{1}{n}\frac{(n+1)n(n-1)}{6}=\frac{(n+1)(n-1)}{6} \qquad (7)$$

and that

$$TI=\sum_{i=1}^{n}i=\frac{(n+1)n}{2}. \qquad (8)$$

The equality $TRD=\frac{1}{n}\sum_{i=1}^{n-1}\sum_{k=1}^{i}k$ in (7) follows from the observation that the relative deprivation of individual $n-i$ is given by $\frac{1}{n}\sum_{k=1}^{i}k$. For example, the relative deprivation of individual $n-1$ is $\frac{1}{n}$, the relative deprivation of individual $n-2$ is $\frac{1+2}{n}$, and so on. The equality $\sum_{i=1}^{n-1}\frac{(i+1)i}{2}=\frac{(n+1)n(n-1)}{6}$ in (7) is an application of a known formula for the $(n-1)^{th}$ tetrahedral number.[10] With (7) and (8) in place, we get that $G\big|_{y_i=i}=\frac{TRD}{TI}\Big|_{y_i=i}=\frac{n-1}{3n}$. Then, conditional on $y_i=i$ and upon drawing on (7) and (8), (6) takes the form

$$\frac{dG}{dy_k}\bigg|_{y_i=i}=\frac{\frac{(2k-1-n)}{n}\frac{(n+1)n}{2}-\frac{(n+1)(n-1)}{6}}{\left(\frac{(n+1)n}{2}\right)^2}=\frac{(n+1)\left(k-\frac{2n+1}{3}\right)}{\left(\frac{(n+1)n}{2}\right)^2}. \qquad (9)$$

The requirement $\frac{dG}{dy_k}>0$ is therefore equivalent to the requirement $k>\frac{2n+1}{3}$. Thus, in this specific case where incomes are equally spaced, we obtain that the pivotal k is $\left\lfloor\frac{2n+1}{3}\right\rfloor+1$. Therefore, for $i\geq\left\lfloor\frac{2n+1}{3}\right\rfloor+1$ the *TRD* effect will dominate the *TI* effect, resulting in $\frac{dG}{dy_i}>0$. And in the complementary domain, namely for $i\in\left\{\left\lfloor\frac{n+1}{2}\right\rfloor+1,\ldots,\left\lfloor\frac{2n+1}{3}\right\rfloor\right\}$, even though both *TRD* and *TI* increase, $\frac{dG}{dy_i}\leq 0$.

[10] The summation is for $n-1$ individuals because the relative deprivation of individual n is nil.

4. Revisiting Sen's social welfare function

Sen (1973 and 1997), Sen (1976), and Sen (1982) sought to measure social welfare by means of the function, *SWF*, formulated as $\mu(1-G)$, namely as the product of income per capita, $\mu = \frac{\sum_{i=1}^{n} y_i}{n}$, and one minus *G*, where *G* is as defined in (3). Expanding the *SWF* function while substituting from (4), we get that

$$SWF \equiv \mu(1-G) = \frac{TI}{n}\left(1-\frac{TRD}{TI}\right) = \frac{1}{n}(TI-TRD)\,. \qquad (10)$$

We see that the welfare of a population of a given size, *n*, is "damaged" by the population's aggregate relative deprivation. The reason why income inequality lowers welfare is not aversion to inequality per se but, rather, aversion to stress; the higher the stress (the higher is *TRD*), the lower the welfare. The $\frac{1}{n}(TI-TRD)$ representation in (10) implies that the statistically based social welfare function $\mu(1-G)$ is transformed into a social-psychological-based social welfare function.

Because for a given sum of income differences (meaning for a given magnitude of the numerator *TRD* of the Gini coefficient) the higher the population's aggregate income (meaning the bigger the magnitude of the denominator $\sum_{i=1}^{n} y_n$ of the Gini coefficient) the lower the Gini coefficient (recall Remark 1), a higher aggregate income affects Sen's social welfare function *in two ways*: as seen in (10), it increases the income per capita term, and it reduces the Gini coefficient term. Thus, not only do we uncover a social-psychological-based rationale for the choice of the Gini coefficient in Sen's social welfare function, we also uncover a possibility for a positive role of income in that function.

But this is not the entire story. We can state whether a marginal increase in income will increase social welfare, and assess the extent of the increase, basing these determinations on the effects of a marginal increase in income on the μ term and on the *G* term in Sen's social welfare function.

Claim 2. A marginal increase in the income y_k of individual $k \in \{1, 2, \dots, n\}$ increases the level of Sen's social welfare. The magnitude of the increase in social welfare depends negatively on the individual's position in the income distribution.

Proof. It is straightforward to calculate that

$$\frac{dSWF}{dy_k} = \frac{1}{n}\left(\frac{dTI}{dy_k} - \frac{dTRD}{dy_k}\right) = \frac{1}{n}\left(1 - \frac{2k-1-n}{n}\right) = \frac{2(n-k)+1}{n^2}.$$

Because $k \le n$, it follows that $\frac{dSWF}{dy_k} > 0$. Furthermore, $\frac{dSWF}{dy_k}$ is a decreasing function of k. Q.E.D.

This result is revealing in more than one way. At first sight, a marginal increase in an income placed high up in the income distribution will increase both the Gini coefficient term and the per capita income term in $SWF = \mu(1-G)$, so the net effect on the level of social welfare will be indeterminate. But a second look, informed by our analysis of the "anatomy" of the Gini coefficient, reveals that there are three channels through which a marginal increase of income affects social welfare: through μ, *TI*, and *TRD*. Because a marginal increase in any income increases both *TI* (which enters the denominator of the Gini coefficient, $G = \frac{TRD}{TI}$), and the income per capita term μ, the combined effect of these two changes, which operate in the same direction, results in a social welfare gain. When we considered the Gini coefficient alone, the increase in aggregate income *TI* was the only factor at work in "limiting" the positive effect of a marginal increase in income on the *TRD* term in *G* when the marginal increase was of an income high up in the income distribution. When we consider $SWF = \mu(1-G)$, however, there are two constraining factors, so a possible increase of *TRD* "succumbs" to their joint force. A surprising result is that a marginal increase in *any* income does not reduce Sen's social welfare, not even when that increase is in an income high up in the income hierarchy which, for sure, exacerbates *TRD*.

What we witness, which aligns with intuition, is that the position in the income distribution of the income that is affected by a marginal increase bears on *the extent* of the gain in social welfare in such a way that the lower the position, the bigger the gain. The difference is in magnitude, not in sign. This is so because when the marginal increase in income occurs fairly low in the income distribution, it alleviates the relative deprivation of the affected individual greatly; it narrows the income gap with a large number of individuals higher up. Less so when the marginal increase in income occurs higher up in the distribution, and completely the opposite when the marginal increase is high up, as then it relieves the relative deprivation of a few, but exacerbates it for many. Formally, because $\frac{dSWF}{dy_k} = \frac{2(n-k)+1}{n^2}$ decreases with k, the biggest gain in social welfare occurs when a given marginal increase of income is in the income of the poorest individual $(k=1)$, $\frac{dSWF}{dy_1} = \frac{2n-1}{n^2}$. And, conversely, we witness the smallest gain in social welfare when a marginal increase in income is in the income of the richest individual $(k=n)$, $\frac{dSWF}{dy_n} = \frac{1}{n^2}$.

5. Discussion and conclusion

Contrary to a widely held perception, the first interpretation of the Gini coefficient as the sum of the levels of income-related stress that individuals experience when their incomes lag behind the incomes of others is not by Yitzhaki (1979) but by Sen himself: "In any pair-wise comparison the man with the lower income can be thought to be suffering from some depression on finding his income to be lower. Let this depression be proportional to the difference in income. The sum total of all such depressions in all possible pair-wise comparisons takes us to the Gini coefficient." Sen (1973, p. 33). That Sen neither formalized the link between a measure of this stress and the Gini coefficient, nor expanded on the rationale for incorporating the Gini coefficient in his social welfare function, does not diminish the insightfulness of his interpretation. Sen was well aware that there are several ways of measuring inequality - the coefficient of variation, the standard deviation of logarithms, Theil's entropy measure, Atkinson's measure, as well as the Gini coefficient - and he spent much effort in analyzing each of them, identifying advantages and drawbacks.[11]

The intuitive appeal of the Gini coefficient arising from its representation as a ratio between a population's aggregate stress and a population's aggregate income need not

[11] The list of people who analyzed properties of measures of inequality including the Gini coefficient and brief accounts of what they had to offer would likely occupy more space than the space taken up by this paper. A good summary coverage of these contributions is in the Annex part of the 1997 edition of Sen's *On Economic Inequality* book.

however be taken to imply that the coefficient is immune to criticisms other than the ones identified by Sen. We allude to two such criticisms and, fortunately, we are able to address them.

One concern relates to a need to account for people's sensitivity to the rank that they occupy in the income distribution. Adam Smith commented that "the desire of . . . obtaining rank among our equals, is, perhaps, the strongest of all our desires" (Smith 1759, Part VI, Section I, Paragraph 4).[12] Seemingly, the measure in (1) is completely lacking in distaste for low rank; the measure aggregates magnitudes that are cardinal whereas, by definition, rank is an ordinal measure: rank-wise income 1 is second to income 2, as it is to income 20. However, the relative deprivation measure of individual *i* defined in (1) can be rewritten in a different form from that in (1), which reveals that the measure *is* sensitive to rank-related concerns. Upon multiplying and dividing $\frac{1}{n}\sum_{j=i+1}^{n}\left(y_j - y_i\right)$ by $n-i$, we obtain

$$RD_i = \frac{n-i}{n}\left[\frac{1}{n-i}\sum_{j=i+1}^{n}(y_j - y_i)\right] = \frac{1}{n}(n-i)\left(\frac{\sum_{j=i+1}^{n} y_j}{n-i} - y_i\right) = \frac{1}{n}[(n-i)\left(\tilde{y}_i - y_i\right)], \qquad (11)$$

where $\tilde{y}_i \equiv \frac{1}{n-i}\sum_{j=i+1}^{n} y_j$ is the average income of the individuals whose incomes are higher than the income of individual *i* (these are the individuals who in the income distribution are positioned to the right of individual *i*).

We can thus think of the term $[(n-i)\left(\tilde{y}_i - y_i\right)]$ of RD_i in (11) as the product of a rank term, $n-i$, and a cardinal term, $\left(\tilde{y}_i - y_i\right)$. Seen this way, the measure of relative deprivation (1) has embedded in it a pure rank preference component and a cardinal preference component. This is revealing in the sense that the stress experienced by individual *i* from trailing behind others can be decomposed into the stress from occupying a rank other than the top rank, which is measured by $n-i$, and the stress arising from a positive magnitude of the

[12] Empirical works demonstrate that being ranked lowly is a source of concern (Weiss and Fershtman, 1998). Studies showing this are, for example, of workers (Falk and Ichino, 2006; Mas and Moretti, 2009; Bandiera et al., 2010; Cohn et al., 2014), and of students (Sacerdote, 2001; Hanushek et al., 2003; Azmat and Iriberri, 2010; Bursztyn and Jensen 2015; Garlick, 2018.) Heffetz and Frank (2011) review the significance of social status (rank) in economic affairs.

income differences between the higher incomes of others and one’s own income, which is measured by $\left(\tilde{y}_i - y_i\right)$.

The measure presented in (11) is also telling in that it reveals an asymmetry: holding the incomes of other individuals constant, a reduced income rank of individual *i* always implies an increase of RD_i, but the converse is not true, namely an increase in the relative deprivation of individual *i*, RD_i, does not necessarily imply a decrease in the rank of this individual.

A second concern is that when we look closely at the population’s aggregate stress component of the Gini coefficient, we see that comparisons with others who are positioned to the right of the reference individual in the income distribution count equally: the income excesses of those who are close by and the income excesses of those who are farther away are accorded equal importance. However, and for example, people might be more disturbed by a given increase in income of an already relatively rich individual in their comparison group than by an equal increase in income of a not so rich individual in their comparison group. The architecture of the numerator of the Gini coefficient is such that this term cannot accommodate this type of sensitivity. But this deficiency is not beyond repair. In Stark et al. (2017), the employment of a set of axioms yielded a new class of generalized measures of relative deprivation, based on a preference relationship defined on the set of vectors of incomes. The class takes the form of a power mean of order p. A characteristic of the class is that it is capable of accommodating both a decreasing weight (the case of $p > 1$), and an increasing weight (the case of $p \in (0,1)$) accorded to given changes in the incomes of the individuals whose incomes are higher than the income of the reference individual. The incentive for introducing the class arose from acknowledgement of the possibility that the weights that an individual assigns to the incomes of individuals whose incomes are higher than his could depend on the proximity in the income hierarchy of those incomes to his income. *TRD* in (2) is a special case of the class when *p* is equal to one, namely when a given change in income, say an increase, of a higher-income individual affects the reference individual equally, regardless of whom to his right receives the increase. Once this class, TRD_p, is imported into G, we obtain both a richer variant of the coefficient and, correspondingly, a generalized characterization, $\frac{1}{n}(TI - TRD_p)$, of Sen's social welfare function in (10).

When evaluating policies that affect both economic growth and the degree of equality in income distribution, a standard protocol has been to base the assessment on a social welfare function. This paper deepens our understanding of Sen's social welfare function and of the repercussions of drawing on that function as a guide to policy formation. Claim 2 reveals that Sen's social welfare function favors *any* economic growth (*any* increase of income); not because the function disregards inequality but, rather, in spite of the function accommodating inequality. Still, when economic growth benefits individuals who occupy the bottom of the income hierarchy, then the gain in social welfare will be the largest. There are settings in which the concern of public policy makers is exclusively with inequality, as when, for example, in the population of interest there is no poverty and everyone has a comfortable level of living. In such a case, the Gini coefficient assumes the same role as the role fulfilled by Sen's social welfare function in the general setting. When the Gini coefficient is "at the helm," Claim 1 provides a clear guide as to the part of the income distribution that should be targeted favorably by public policy.

Appendix A: Construction of the index of relative deprivation

Several recent insightful studies in social psychology (for example, Callan et al., 2011; Smith et al., 2012) document how sensing relative deprivation, *RD*, impacts negatively on personal wellbeing, but these studies do not provide a calibrating procedure; a sign is not a magnitude. For the purpose of constructing a measure, a natural starting point is the work of Runciman (1966), who argued that an individual has an unpleasant sense of being relatively deprived when he lacks a desired good and perceives that others with whom he naturally compares himself possess that good. Runciman (1966, p. 19) writes as follows: “The more people a man sees promoted when he is not promoted himself, the more people he may compare himself with in a situation where the comparison will make him feel deprived,” thus implying that the deprivation from not having, say, income y is an increasing function of the fraction of people in the individual’s reference group who have y. To aid intuition, we resort to income-based comparisons, namely an individual feels relatively deprived when others in his reference group earn more than he does. It is assumed here implicitly that the earnings of others are publicly known. Alternatively, we can think of consumption, which might be more publicly visible than income, although these two variables can reasonably be assumed to be strongly positively correlated.

As an illustration of the relationship between the fraction of people possessing income y and the deprivation of an individual lacking y, consider a population (reference group) of six individuals with incomes {1,2,6,6,6,8}. Imagine a furniture store that in three distinct departments sells chairs, armchairs, and sofas. An income of 2 allows you to buy a chair. To be able to buy an armchair, you need an income that is a little bit higher than 2. To buy any sofa, you need an income that is a little bit higher than 6. Thus, when you go to the store and your income is 2, what are you “deprived” of? The answer is “armchairs” and “sofas.” Mathematically, this deprivation can be represented by $P(Y > 2)(6-2) + P(Y > 6)(8-6)$, where $P(Y > y_i)$ stands for the fraction of those in the population whose income is higher than y_i, for $y_i = 2, 6$. The reason for this representation is that when you have an income of 2, you cannot afford anything in the department that sells armchairs, and you cannot afford anything in the department that sells sofas. Because not all those who are to your right in the ascendingly ordered income distribution can afford to buy a sofa, yet they can all afford to buy armchairs, a breakdown into the two (weighted) terms $P(Y > 2)(6-2)$ and

$P(Y>6)(8-6)$ is needed. This way, we get to the essence of the measure of *RD* presented in the main text of the paper: we take into account the fraction of the reference group (population) who possess some good which you do not, and we weigh this fraction by the "excess value" of that good. Because income enables an individual to afford the consumption of certain goods, we refer to comparisons based on income.

Formally, let $y=(y_1,...,y_m)$ be the vector of incomes in population *N* of size *n* with relative incidences $p(y)=\left(p(y_1),...,p(y_m)\right)$, where $m\le n$ is the number of distinct income levels in *y*, where *n* and *m* are natural numbers. The *RD* of an individual earning y_i is defined as the weighted sum of the excesses of incomes higher than y_i such that each excess is weighted by its relative incidence, namely

$$RD_N(y_i)\equiv\sum_{y_k>y_i}p(y_k)(y_k-y_i)\,. \qquad \text{(A1)}$$

In the example given above with income distribution {1,2,6,6,6,8}, we have that the vector of incomes is $y=(1,2,6,8)$, and that the corresponding relative incidences are $p(y)=(1/6,1/6,3/6,1/6)$. Therefore, the *RD* of the individual earning 2 is $\sum_{y_k>y_i}p(y_k)(y_k-y_i)=p(6)(6-2)+p(8)(8-2)=\frac{3}{6}\cdot4+\frac{1}{6}\cdot6=3$. By similar calculations, we have that the *RD* of the individual earning 1 is higher at $3\frac{5}{6}$, and that the *RD* of each of the individuals earning 6 is lower at $\frac{1}{3}$.

We expand the vector y to include incomes with their possible respective repetitions, that is, we include each y_i as many times as its incidence dictates, and we assume that the incomes are ordered, that is, $y=(y_1,...,y_n)$ such that $y_1\le y_2\le...\le y_n$. In this case, the relative incidence of each y_i, $p(y_i)$, is $1/n$, and (1), defined for $i=1,...,n-1$, becomes

$$RD_N(y_i)\equiv\frac{1}{n}\sum_{k=i+1}^{n}\left(y_k-y_i\right). \qquad \text{(A1')}$$

Looking at incomes in a large population, we can model the distribution of incomes as a random variable *Y* over the domain $[0,\infty)$ with a cumulative distribution function *F*. We can then express the *RD* of an individual earning y_i as

$$RD_N\left(y_i\right) = \left[1 - F(y_i)\right] \cdot E\left(Y - y_i \mid Y > y_i\right). \quad \text{(A2)}$$

To obtain this expression, starting from (A1), we proceed in the following manner:

$$\begin{aligned} RD_N(y_i) &\equiv \sum_{y_k > y_i} p(y_k)(y_k - y_i) \\ &= \sum_{y_k > y_i} p(y_k) y_k - y_i \sum_{y_k > y_i} p(y_k) \\ &= [1 - F(y_i)] \sum_{y_k > y_i} \frac{p(y_k) y_k}{[1 - F(y_i)]} - y_i [1 - F(y_i)] \\ &= [1 - F(y_i)] E(Y \mid Y > y_i) - [1 - F(y_i)] y_i \\ &= [1 - F(y_i)] E(Y - y_i \mid Y > y_i). \end{aligned}$$

The representation in (A2) states that the *RD* of an individual whose income is y_i is equal to the product of two terms: $1 - F\left(y_i\right)$, which is the fraction of those individuals in the population of n individuals whose incomes are higher than y_i, and $E(Y - y_i \mid Y > y_i)$, which is the mean excess income.

The formula in (A2) is quite revealing because it casts *RD* in a richer light than the ordinal measure of rank or, for that matter, even the ordinal measure of status, which have been studied intensively in sociology and beyond. The formula informs us that when the income of individual A is, say, 10, and that of individual B is, say, 16, the *RD* of individual A is higher than when the income of individual B is 15, even though, in both cases, the rank of individual A in the income hierarchy is second. The formula also informs us that more *RD* is sensed by an individual whose income is 10 when the income of another is 14 (*RD* is 2) than when the income of each of four others is 11 (*RD* is $\frac{4}{5}$), even though the excess income in both cases is 4. This property aligns nicely with intuition: it is more painful (more stress is experienced) when the income of half of the population in question is 40 percent higher than when the income of $\frac{4}{5}$ of the population is 10 percent higher. In addition, the formula in (A2) reveals that even though *RD* is sensed by looking to the right of the income distribution, it is impacted by events taking place on the left of the income distribution. For example, an exit from the population of a low-income individual increases the *RD* of higher-income individuals (other than the richest) because the weight that the latter attach to the difference between the incomes of individuals “richer” than themselves and their own income rises.

Similar reasoning can explain the demand for positional goods (Hirsch, 1976). The standard explanation is that this demand arises from the unique value of positional goods in elevating the social status of their owners (“These goods [are] sought after because they compare favorably with others in their class.” Frank, 1985, p. 7). The distaste for relative deprivation offers another explanation: by acquiring a positional good, an individual shields himself from being leapfrogged by others which, if that were to happen, would expose him to *RD*. Seen this way, a positional good is a form of insurance against experiencing *RD*.

Appendix B: A brief historical account of the "adoption" of the sociological-psychological concept of relative deprivation by the discipline of economics

A considerable amount of economic analysis has been inspired by the sociological-psychological concepts of relative deprivation (*RD*) and reference (comparison) groups.[13] Economists have come to consider these concepts as appropriate tools for studying comparisons that affect an individual's perception of wellbeing and behavior, and - in particular - comparisons with related individuals whose incomes are higher than his own income (consult the large literature spanning from Duesenberry, 1949, to, for example, Clark et al., 2008). An individual has an unpleasant sense of being relatively deprived when he lacks a desired good and perceives that others in his reference group possess that good (Runciman, 1966). Given the income distribution of the individual's reference group, the individual's *RD* is the sum of the deprivation caused by every income unit that he lacks (Yitzhaki, 1979; Ebert and Moyes, 2000; Stark et al., 2017).

The pioneering study in modern times that opened the way to research on *RD* and primary (reference) groups is the 1949 two-volume set of Stouffer et al. *Studies in Social Psychology in World War II: The American Soldier.* That work documented the distress caused not by a low military rank and weak prospects of promotion (in the military police) but rather by the faster pace of promotion of others (in the air force). It also documented the lesser dissatisfaction of black soldiers stationed in the South who compared themselves with black civilians in the South than the dissatisfaction of their counterparts stationed in the North who compared themselves with black civilians in the North. Stouffer's research was followed by a large social-psychological literature. Economics has caught up relatively late, and only partially. This is rather surprising because eminent economists in the past understood well that people compare themselves to others around them, and that social comparisons are of paramount importance for individuals' happiness, motivation, and actions. Even Adam Smith (1776) pointed to the social aspects of the necessities of life, and stressed the *relative* nature of poverty: "A linen shirt, for example, is, strictly speaking, not a necessary of life. The Greeks and Romans lived, I suppose, very comfortably, though they had no linen. But in the present times, through the greater part of Europe, a creditable day-laborer would be ashamed to appear in public without a linen shirt, the want of which would be supposed to denote that

[13] The reference (comparison) group of an individual is the set of individuals with whom the individual naturally compares himself. (Consult Runciman, 1966; Singer, 1981.)

disgraceful degree of poverty […]" (p. 465). Marx's (1849) observations that "Our wants and pleasures have their origin in the society; [… and] they are of a relative nature" (p. 33) emphasize the social nature of utility and the impact of an individual's relative position on his satisfaction. Inter alia, Marx wrote: "A house may be large or small; as long as the surrounding houses are equally small, it satisfies all social demands for a dwelling. But if a palace arises beside the little house, the house shrinks into a hut" (p. 33). Samuelson (1973), one of the founders of modern neoclassical economics, pointed out that an individual's utility does not depend only on what he consumes in *absolute* terms: "Because man is a social animal, what he regards as 'necessary comforts of life' depends on what he sees others consuming" (p. 218).

The relative income hypothesis, formulated by Duesenberry (1949), posits an asymmetry in the comparisons of income which affect the individual's perception of wellbeing: the individual looks upward when making comparisons. Veblen's (1899) concept of *pecuniary emulation* explains why the behavior of an individual can be influenced by comparisons with the incomes of those who are richer. Because income determines the level of consumption, higher income levels may be the focus for emulation. Thus, an individual's income aspirations (to obtain the income levels of other individuals whose incomes are higher than his own) are shaped by the perceived consumption standards of the richer individuals. In that way, invidious comparisons affect behavior, that is, behavior which leads to "the achievement of a favourable comparison with other men […]" (Veblen, 1899, p. 33).[14]

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[14] The empirical findings support the relative income hypothesis. Duesenberry (1949) already found that individuals' levels of savings depend on their positions in the income distribution, and that the incomes of the richer people affect the behavior of the poorer ones (but not *vice versa*). Later on, and for example, Schor (1998) showed that, keeping annual and permanent income constant, individuals whose incomes are lower than the incomes of others in their community save significantly less than those in their community who are relatively better off.

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