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Sated but Thirsty: A Prolegomenon to Multidimensional Measures of Need-Based Justice

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Abstract
In attempts to compare different distributions with regards to need, so-called "measures of need-based distributive justice" have emerged in recent years. Each of the proposed measures relies on a single dimension of need that is taken into account. This is shown to be problematic since humans experience different kinds of need that appear to be incommensurable. A strategy to deal with this problem is introduced by using multidimensional measures.

Keywords Distributive justice · Need-based justice · Metrics · Multidimensional measurement · Formal modeling

1 Introduction

Need plays an important role for considerations on distributive justice, being one of the few major categories that are generally considered relevant in this area (Forsyth 2006). There are several attempts of measuring the justice of some given allocation, often with a focus on inequality (Gini 1914; Atkinson 1970; Firebaugh 1999; Lambert 2001). From a sociological point of view, Jasso (1999, 2007, Jasso and Wegener 1997) prominently introduced general metrics of (perceived) justice. In an early paper, Jasso (1978) refers to a number of other suggestions by Homans (1961), Adams (1965), Berger et al. (1972), as well as Walster et al. (1973). Eriksson (2012) discusses further rudimentary metrics referring to Jasso. Additionally, Braß (1994) considers problems of fair representation as a mathematical problem of distributive justice.

Attempts of measuring distributive justice with respect to *need* are relatively scarce, including a rudimentary approach by Miller (1999) and considerations by Hassoun (2009). Bauer (2017a, b) suggests a modified index that is borrowed from

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the measurement of poverty; Siebel (2017) recalls concepts from classical antiquity for this purpose; Traub et al. (2017) introduce an index that satisfies a set of axioms proposed to be important for the measurement of need-based justice; and Springhorn (2017) introduces a measure that focuses on the perspective of a single individual within a given distribution.

These attempts—however diverse—in general propose a one-dimensional reference point; a person gets attributed a single value quantifying its legitimate claim and a single value representing its actual stake. Take, for example, a one-dimensional measure (here denoted O) from Jasso (1999) that can be stated as follows:

$$O_{Jasso}(x, y) = \frac{1}{n} \sum_{i=1}^{n} \ln \left(\frac{x_i}{y_i} \right)$$

Here, she suggests the arithmetic mean for the aggregation of the justice evaluation functions of several individuals i. Those functions consist of the natural logarithm of the quotient of some normative target value (y) and the actual allocation (x) of the individuals (i).

To name another recent example, Bauer (2017a, b) proposes a measure that is a modified version of a widely used poverty index introduced by Foster et al. (1984):

$$O_{Bauer}(x, y) = \frac{u}{p} \sum_{i \in \mathcal{U}} \left(\frac{(y_i - x_i)}{x} \right)^{\alpha} + \frac{o}{p} \sum_{i \in \mathcal{O}} \left(\frac{(x_i - y_i)}{y} \right)^{\beta}$$

Here, it is suggested to take the oversupplied ($\mathcal{O}$) and undersupplied ($\mathcal{U}$) individuals into account separately using two different sums, weighted by their share of the whole population ($\mathcal{P}$). Powers (α, β) are given as parameters of aversion against or affinity for under- respectively oversupply.

Such reductions to a single dimension—in this case y_i as the single normative reference point for the need of some individual i and x_i as the corresponding actual allocation—appear to be problematic in the case of need-based justice: The concept of need is—in stark contrast to the models recently proposed—a multidimensional one that can hardly be broken down into a single-dimensional value. People have a variety of needs and there even appears to be some kind of incommensurability between some of those.[1]

The need for water and the need for food, to choose a simple example from the class of biologically motivated basic needs, both count (probably without question) as legitimate. Nonetheless, it appears to be problematic to attribute a single value

[1] For similar reasons, economic research on poverty measurement has put forth the use of net equivalent incomes or multidimensional approaches (Kapteyn and van Praag 1976, van Praag 1977, Atkinson and Bourguignon 1987, Ebert and Moyes 2003, Jenkins and Lambert 2005). Some approaches, for example, make use of subjective poverty lines (Goedhart et al. 1977, Flink and van Praag 1991), others try explicitly to be multidimensional (Bourguignon and Chakravarty 2003, Alkire and Foster 2011, Kakwani and Silber 2008). There is also measurement of inequality and welfare with heterogeneous needs, proposed by, among others, Atkinson and Bourguignon (1987) as well as Lambert and Ramos (2002, see Chakravarty 2009). Furthermore, the Human Development Index may come to mind (see Stanton 2007).

of need to a person that feels both hunger and thirst, because those needs usually demand different goods for their satisfaction. Assuming that, summing up two numbers that represent a person's need for hydration and their need for nutrition leads to problems: Take, for example, a need of five units of drinking to satisfy a person's need for hydration and an additional need of five units of nourishment to satisfy their need for nutrition, adding up to a total need of ten units to satisfy this person's need. Now assume that this individual receives a total of ten units of food. Relying solely on the aggregated and dimensionless values of needing ten units and receiving ten units, we would expect the person to be satisfied—though even unlimited supplies of one kind of food may not be able to meet their need for water.

Considering, for example, Maslow's (1943) proposed hierarchy of needs, this problem can easily be extended to further categories of need. Besides this prominent example from motivational psychology, many philosophers have also stated that needs can be sorted into groups. There are countless such typologies of need (see, e.g., Dean 2010; Bauer 2019a; Siebel and Schramme 2020). To give an example, Brock (2005, p. 63) argues that human agency depends on the ability to deliberate and choose. This ability requires "physical and mental health", "sufficient security to be able to act", as well as "a certain amount of autonomy". Those constitute different kinds of need, each bearing a normative force on its own. Or think of Braybrooke (1987, p. 36), who argues that "physical functioning" necessitates things like food, excretion, exercise, and rest, while "functioning as a social being" requires companionship, education, social acceptance, and the like. This fundamental feature of the concept of need should be taken into account when constructing a measure of need-based justice.[2] Therefore, a first suggestion on how to tackle this problem is to be introduced in the following.

2 Notation and Definitions

First of all, a formal notation is to be introduced that has to include those aspects that are considered relevant. Of course, that already requires a selection, which is never free from normative assumptions.

To begin, a set $\mathcal{P}$ of individuals $i = \{1, \ldots, n\}$ is considered, their number is given by $p = \#(\mathcal{P})$. These individuals do not have to represent singular persons, they also can describe groups (e.g., households or institutions). It is assumed that every individual i exhibits need in several dimensions $j = \{1, \ldots, m\}$, giving us v_i^j that is to be quantified within the nonnegative real numbers, $v_i^j \in \mathbb{R}_0+$.

[2] This is also of relevance for empirical research concerned with needs. In recent years—dating back at least to Yaari and Bar-Hillel (1984)—a fair number of empirical studies has emerged, investigating the role of need in laypeople's evaluations or decisions concerning distribution problems (Pritzlaff-Scheele and Zauchner 2017, Weiß et al. 2017, Bauer 2018, Bauer 2019b, Bauer et al. 2020, Diederich et al. 2020, Kittel et al. 2020, Wyszynski et al. 2020). Here, too, the focus is usually on a single dimension of need. Since the findings of empirical research can (re-)enter normative discourse (Bauer and Meyerhuber 2019, 2020), it is especially important to take into account such reflections.

Definition 1 (Need). *An individual i experiences need ν in some dimension $j = \{1, \ldots, m\}$, which is denoted as ν_i^j. It is quantified within the nonnegative real numbers, $\nu_i^j \in \mathbb{R}_0+$.*

For some individual i one can then denote ν_i^1 to ν_i^m needs. For a set $\mathcal{P}$ of individuals $i = \{1, \ldots, n\}$ this gives us a matrix N of needs for all ν_i^j as $N = \left(\nu_i^j\right)$ with $\nu_i^j > 0$ for $j = \{1, \ldots, m\}$ and $i = \{1, \ldots, n\}$.

$$N = \begin{pmatrix} \nu_1^1 & \nu_1^2 & \cdots & \nu_1^m \\ \nu_2^1 & \nu_2^2 & \cdots & \nu_2^m \\ \vdots & \vdots & \ddots & \vdots \\ \nu_n^1 & \nu_n^2 & \cdots & \nu_n^m \end{pmatrix}$$

Furthermore, it is assumed that every individual i has available actual allocations of some goods γ_i^j for each need, also quantified within the nonnegative real numbers, $\gamma_i^j \in \mathbb{R}_0+$. The allocated goods do not have to be limited to physical goods, but they do have to be quantifiable. It can be assumed that there are different goods for the satisfaction of different needs, for simplification also consisting of dimensions $j = \{1, \ldots, m\}$ representing m dimensions of goods for the m dimensions of needs.

Definition 2 (Endowment). *An individual i posses an endowment γ in some dimension $j = \{1, \ldots, m\}$, which is denoted as γ_i^j. It is quantified within the nonnegative real numbers, $\gamma_i^j \in \mathbb{R}_0+$.*

This way, for simplification, it is not taken into account that sometimes several goods may satisfy the same needs or that the same good can satisfy different needs. A matrix G of goods for all γ_i^j can be obtained as $G = \left(\gamma_i^j\right)$ with $\gamma_i^j > 0$ for $j = \{1, \ldots, m\}$ and $i = \{1, \ldots, n\}$.

$$G = \begin{pmatrix} \gamma_1^1 & \gamma_1^2 & \cdots & \gamma_1^m \\ \gamma_2^1 & \gamma_2^2 & \cdots & \gamma_2^m \\ \vdots & \vdots & \ddots & \vdots \\ \gamma_n^1 & \gamma_n^2 & \cdots & \gamma_n^m \end{pmatrix}$$

Now γ_i^j and ν_i^j can be used to determine whether some individual i is to be considered as undersupplied, supplied or oversupplied with regard to a specific dimension of need. From this classification, the subsets $\mathcal{U}$, $\mathcal{S}$, and $\mathcal{O}$ can be obtained from the set $\mathcal{P}$. An individual is considered as undersupplied with regard to some good if they have smaller resources in this dimension than their corresponding need. They are considered as supplied with regard to some good if their resources equal their need in this dimension. Finally, they are considered as oversupplied with regard to some good if their resources exceed their corresponding need.

Definition 3 (Undersupply). *An individual i is undersupplied in some dimension of need j if $\gamma_i^j < \nu_i^j$. The set of undersupplied individuals contains every individual that*

is undersupplied in at least one dimension; it is denoted as $\mathcal{U} = \{i \in \mathcal{P} : \exists j(\gamma_i^j < \nu_i^j)\}$ *; their number is given by* $u = \#(\mathcal{U})$.

Definition 4 (Supply). *An individual* i *is supplied in some dimension of need* j *if* $\gamma_i^j = \nu_i^j$. *The set of supplied is* $\mathcal{S} = \left\{ i \in \mathcal{P} : \forall j\left(\gamma_i^j = \nu_i^j\right) \right\}$; *their number is given by* $s = \#(\mathcal{S})$.

Definition 5 (Oversupply). *An individual* i *is oversupplied in some dimension of need* j *if* $\gamma_i^j > \nu_i^j$. *The set of oversupplied is* $\mathcal{O} = \left\{ i \in \mathcal{P} : \forall j\left(\gamma_i^j \geq \nu_i^j\right) \right\}$; *their number is given by* $o = \#(\mathcal{O})$.

At this point, a first classification of individuals is already possible: For example, the union criterion of multidimensional measurement of poverty could be adopted, as has been done in the definitions above. It could then be stated that every individual that suffers undersupply in at least one dimension counts as undersupplied in general. Alternatively, the intersection criterion could be considered: Then, an individual has to fall short in every dimension to be regarded as undersupplied. Of course, these approaches are only two extremes of a wide variety of possible options (see, e.g., Alkire and Santos 2013).

3 A Tentative Multidimensional Measure of Need-Based Justice

As a first step to obtain a multidimensional measure of need-based justice, a subtraction of the matrices can be performed with $G - N$, as follows, to obtain the status of supply for every individual in every dimension that is represented.

$$\begin{pmatrix} \gamma_1^1 & \gamma_1^2 & \cdots & \gamma_1^m \\ \gamma_2^1 & \gamma_2^2 & \cdots & \gamma_2^m \\ \vdots & \vdots & \ddots & \vdots \\ \gamma_n^1 & \gamma_n^2 & \cdots & \gamma_n^m \end{pmatrix} - \begin{pmatrix} \nu_1^1 & \nu_1^2 & \cdots & \nu_1^m \\ \nu_2^1 & \nu_2^2 & \cdots & \nu_2^m \\ \vdots & \vdots & \ddots & \vdots \\ \nu_n^1 & \nu_n^2 & \cdots & \nu_n^m \end{pmatrix}$$

This results in a negative value for undersupply, a zero for supply, and a positive value for oversupply, providing a first impression of the supply situation across all considered dimensions of need for every individual.

For illustration, a set $\mathcal{P}$ of individuals $i = \{1, 2, 3\}$ is assumed. Every individual exhibits individual needs ν_i^j that are expressed in four different dimensions $j = \{1, 2, 3, 4\}$, take, for example, hydration, nourishment, living space, and recreational time. For sake of simplification, the problem will be set aside that, usually, those dimensions are all measured in different units (e.g., millilitres, calories, square meters, and hours). This results in a matrix N of needs for all ν_i^j with $N = \left(\nu_i^j\right)$. For simplification, it is assumed that every individual has the same quantification of need—say five units—across all four dimensions.

$$N = \begin{pmatrix} 5 & 5 & 5 & 5 \\ 5 & 5 & 5 & 5 \\ 5 & 5 & 5 & 5 \end{pmatrix}$$

In addition, it is assumed that there are different goods for the satisfaction of different needs that are allocated heterogeneously among these individuals and their needs. This may give us a matrix G of goods for all γ_i^j with $G = \left(\gamma_i^j\right)$ as follows.

$$G = \begin{pmatrix} 3 & 2 & 0 & 0 \\ 5 & 5 & 5 & 5 \\ 3 & 2 & 7 & 8 \end{pmatrix}$$

If these matrices are subtracted with $G - N$, it provides insight into the status of supply for every individual in every dimension of need.

$$G - N = \begin{pmatrix} -2 & -3 & -5 & -5 \\ 0 & 0 & 0 & 0 \\ -2 & -3 & 2 & 3 \end{pmatrix}$$

It becomes clear that the first individual is undersupplied in every dimension, while the second one is overall supplied. The third one however suffers undersupply in two dimensions while being oversupplied in two others. Based on the above mentioned union criterion, for example, it can now be stated that every individual that suffers some undersupply in at least one dimension counts as undersupplied in general, those whose needs are exactly met in every dimension count as supplied, and those whose needs are oversupplied in at least one dimension while not suffering undersupply in any other count as oversupplied. This in mind, the subsets of the undersupplied ($\mathcal{U}$), supplied ($\mathcal{S}$), and oversupplied ($\mathcal{O}$) individuals in $\mathcal{P}$ can be obtained.

$$i \in \begin{cases} \mathcal{U} \;\; if\, i \in \mathcal{P} : \exists j(\gamma_i^j < v_i^j) \\ \mathcal{S} \;\; if\, i \in \mathcal{P} : \forall j\left(\gamma_i^j = v_i^j\right) \\ \mathcal{O} \;\; if\, i \in \mathcal{P} : \nexists j(\gamma_i^j < v_i^j) \wedge \exists j(\gamma_i^j > v_i^j) \end{cases}$$

Therefore, none of the three individuals counts as oversupplied, although one is oversupplied in two dimensions of need; one individual counts as supplied, and the others as undersupplied.

As for the one-dimensional measurement of need-based justice, this can now be aggregated to some multidimensional index M of need-based justice. It is possible, for example, to construct a multidimensional enhancement of the poverty measure of Foster and colleagues, as stated by Kockläuner (2012). Nonetheless, another approach is chosen here.

First of all, a basic assumption has to be recalled: In every case, it should make a difference whether a person gains or looses some of their supply, assuming their need stays the same (Bauer 2018, 2019b). The measure should capture

that, depicting a monotonicity of justice evaluation that is gradually dependent on the supply an individual has in some dimension of need (Bauer 2018, 2019b). The justice evaluation of the measure—let it be denoted $M(\nu, \gamma)$—can therefore be understood as a monotonic function. It can be distinguished between several forms of monotonicity: The measure can be strictly increasing or strictly decreasing, for example. The former is the case if an increase in supplies leads to a greater justice of the distribution; so if $\gamma_i^j < \gamma_i^{j\prime}$ then $M(\nu, \gamma) > M\left(\nu, \gamma'\right)$. The latter is the case if an increase in supplies leads to a lower justice of the distribution; so if $\gamma_i^j < \gamma_i^{j\prime}$ then $M(\nu, \gamma) < M\left(\nu, \gamma'\right)$, whereby the measure M as a justice evaluation function can be sectionally defined with different monotonic properties.

Why is this sectional definition important? For the case of undersupply, it seems pretty clear what kind of monotonicity is required: As long as comparative considerations (Feinberg 1974; Springhorn 2017) are left aside and we therefore do not have to deal with inequality among the considered individuals, it can be assumed that an additional unit of some good states an approximation to the legitimate need as long as the individual was initially undersupplied. Therefore, the measure should be strictly monotonically increasing for the case of undersupply. Now how about the case of oversupply? Should the measure be strictly monotonically increasing, too, or should it instead be strictly decreasing? And if so, why?

For example, and for the sake of the argument, let us consider that an exact alignment of need and allocation constitutes an ideal state of distribution.[3] Therefore, the measure should be strictly decreasing in the case of oversupply. This could be motivated with conceptions known from classical antiquity, for example, the μεσότης (*mesotes*), or recent debates about sufficiency. This in mind, the following could be adopted for the measurement of needs-based justice:

$$M(\nu, \gamma) = \frac{1}{m} \sum_{j=1}^{m} \prod_{i=1}^{n} \left(1 - \left| \frac{\left(\gamma_i^j - \nu_i^j \right)}{\gamma_i^j + \nu_i^j} \right| \right)$$

Here, a similarity measure, namely the *Earth Similarity Index* as proposed by Schulze-Makuch et al. (2011), is transformed to measure the similarity of the actual allocation to the proclaimed needs, summing it up for every individual divided by their whole number. The *Earth Similarity Index* is a variation of the similarity index from Bray and Curtis (1957, see Bloom 1981). It gives a number between 0—for no similarity—and 1—for being identical—for the comparison of two states.

[3] Alternative assumptions are covered in Bauer (2018).

4 Conclusion

It has been pointed out that one-dimensional measures of need-based justice struggle with a conceptual problem that can be overcome by constructing multidimensional measures. One example of a possible index has been shortly introduced.

This attempt could be pushed even further, allowing for the construction of a general index for distributive justice, incorporating, for example, the four dimensions of equality (ε), efficiency (μ), desert (δ), and need (ν), combining them in a single matrix D as follows:

$$D = \begin{pmatrix} \varepsilon_1 & \mu_1 & \delta_1 & \nu_1^1 & \cdots & \nu_1^m \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ \varepsilon_n & \mu_n & \delta_n & \nu_n^1 & \cdots & \nu_n^m \end{pmatrix}$$

These dimensions could be further split up into different sub-dimensions—as depicted above for the category of need –, which could lead to interesting new areas of inquiry.

One way or the other, this *Prolegomenon* is merely a hint at the possibilities of measuring the justice of a given distribution. Throughout the text, important normative decisions that are not at all uncontested were made, oftentimes for the sake of brevity or simplicity. This paper presents a core idea, not a sophisticated measure of need-based justice. That is still a task for the future.

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