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Accounting for subsistence needs in non-market valuation: A simple proposal[0]

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Abstract

Revealed and stated preference techniques are widely used to assess willingness to pay (WTP) for non-market goods as input to public and private decision-making. However, individuals first have to satisfy subsistence needs through market good consumption, which affects their ability to pay. We provide a methodological framework and derive a simple *ex post* adjustment factor to account for this effect. We quantify its impacts on the WTP for non-market goods and the ranking of projects theoretically, numerically and empirically. This confirms that non-adjusted WTP tends to be plutocratic: the views of the richest - whatever they are - are more likely to impact decision-making, potentially leading to ranking reversal between projects. We also suggest that the subsistence needs-based adjustment factor we propose has a role to play in value transfer procedures. The overall goal is a better representation of the entire population's preferences with regard to non-market goods.

Keywords: subsistence needs; adjustment factor; non-market valuation; value transfer; population's preferences

JEL Codes: D60, D70, Q51

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1. Introduction

Over the past 50 years, non-market goods and services - like ecological services, improved recreation, visual amenities, odours, noise, loss of biodiversity, psychological factors, or the valuation of health - have made their entry into public and private decision-making. With no marketplace to set economic prices for these goods, their values are often assessed by methods based on revealed or stated preferences (SP). These valuation methods elicit individuals' preferences for a given non-market good, either directly through surveys (stated) or indirectly through exploiting market data (revealed). They then derive shadow prices / willingness to pay (WTP) for the corresponding welfare change, and these fuel collective choices, more comprehensive economic assessments like cost-benefit analyses (CBA), or (international) value transfer from one site to another.

The standard project-assessment criterion in CBA is the Kaldor-Hicks compensation test, an extension of the Pareto test for projects involving losers. It states that if the net present value of a project (measured by the discounted sum of individual benefits and costs) is positive, then social welfare is increased and the gainers can compensate the losers with a monetary transfer (Johansson and Kriström, 2018). The seminal rationale was that CBA targets efficiency (as given by the Lindahl-Samuelson condition for public goods) and not distributional issues, which are handled by the tax-transfer system. However, arguments against this rationale rapidly emerged because there is no guarantee that the transfer between gainers and losers will actually take place once the project is implemented. Equity issues (disadvantaged individuals deserve protection, and the losers should be compensated by the gainers) and distributional issues led to the current commonly accepted view that distributional weights are required, and should correspond to the social marginal utility of income, i.e. society's valuation of the individual marginal utility of income (Brent, 2006; Fleurbaey and Abi-Rafeh, 2016; Johansson and Kriström, 2018).

Following Nyborg (2014), we consider that while CBA is a tool that can inform decision-makers on the efficiency of projects involving non-market goods, it cannot be used to measure social welfare effects. We hence adopt a positive rather than normative interpretation of CBA by leaving subjective choices, both on how to aggregate gainers' and losers' individual choices and on the implementation of compensation mechanisms, in the hands of the decision-maker (Hammitt, 2021). S/he will then make choices based on what s/he considers the predominant view of fairness in the population (Sager, 2013; Mouter, 2019), or possibly by looking at how different fairness views affect the decision (Van Wee, 2012). We believe that the major value of CBA lies in providing decision-makers with full and accurate information on individuals' preferences (in particular non-market-related) rather than a definitive final ranking among projects.

Another way in which non-market valuation plays a role in public decision-making is through value transfer (see Johnston et al., 2021; for a recent overview). Multiple studies on different populations and different non-market goods are costly and time-consuming, and require the expertise of specialists. Consequently, in Europe and the United States, governmental and non-governmental bodies often transfer values obtained from studies realized at a study site to a policy site of interest, in order to assess the impacts of regulations or inform policy-making. According to OECD (2018), "Value transfers are the bedrock of practical policy analysis" (p. 157). However, this raises the critical issue of how best to account for income differences between the study and the policy sites, especially in international or interregional value transfers.

These two processes - CBA and value transfer - appear very transparent and consistent with mainstream welfare economics, directly feeding the preferences of the whole population into decision-making. Nevertheless, willingness to exchange or receive money for non-market good provision, while acting as an indicator of public preferences, also depends on the ability to pay (Brent, 2006), with the consequence that the richer are likely to more greatly influence policy decisions (Pearce et al., 2006; Atherton, 2019). There have been proposals to take this into account, *ex ante* by replacing money with a different numéraire (see Brekke, 1997; or Kassahun et al., 2020; for a recent review), or *ex post*, by weighting the WTP (often by a function of income, Donaldson, 1999; Treasury, 2018; or via a structural model; Lee, 2016), or using a social welfare function (SWF, see Adler, 2019). However, *ex ante* approaches call for specific designs, while *ex post* approaches rely on subjective choices in the weighting process or require additional data and complex procedures rarely used in practice.

We propose an alternative to existing approaches, simple to apply *ex post* on any existing data and limiting subjective choices. We start by considering that although many income-based corrections try to capture inequalities, they do not allow for the fact that the irreducible costs of meeting subsistence needs (often pre-incurred) limit individuals' ability to pay. The public economic literature contains some work that takes this into account by considering the effects of subsistence requirements when measuring minimum health conditions (Russell, 1996) or minimum levels for ecosystem services (Baumgärtner et al., 2017b; Drupp, 2018). However, to our knowledge, the impact of individual subsistence needs on WTP for non-market goods has not been explored either theoretically or empirically.

We propose to fill this gap by investigating how individual subsistence needs affect WTP for non-market goods and then the collective choices that involve them. First, we consider how subsistence needs impact individual WTP, and look for a simple *ex post* individual adjustment factor. Second, we introduce heterogeneous preferences towards the non-market good, and examine how subsistence needs affect both the mean WTP for a given project and the likelihood of ranking reversal between two projects with different non-market goods. Finally, we provide both numerical and empirical illustrations for various non-market good preferences.

We find that the subsistence needs issue more strongly impacts the WTP of the poorest individuals than that of the richest, and decreases the monetary assessment of a project at the aggregate level. As a consequence, when a population's preferences are heterogeneous, the views of the richest - whatever they are - are more likely to impact decision-making, a standard result that can be considered a plutocratic partiality. We show how the adjustment factor we propose tackles this issue, and can be theoretically obtained with appropriate distributional weights. We find that ranking reversal between two projects can occur, depending on the preferences of the richest and the poorest. Finally, the empirical application estimates adjustment factors on real data for two countries, using both CBA-type and value transfer-type analyses.

Our contribution is to the methodology of policy choice in presence of non-market goods. We propose a framework for assessing the impact of subsistence needs on individual WTP elicited for non-market goods, and a simple and pragmatic way to adjust *ex post* for this impact. This adjustment factor can be applied to existing data based solely on respondent income and country- and good-specific data. It may precede the application of distributional weights in a CBA or be part of value transfer. This adjustment factor could help decision-makers better account for the preferences of the entire population with regard to non-market goods, which is particularly relevant because poorer households are more exposed to negative environmental externalities (air or water pollution, toxic wastes, noise, natural hazards). Moreover, poor households have disproportionately lower access to positive amenities provided by the natural environment (recreational and aesthetic resources) and it is harder for the poor to combat negative environmental externalities through costly behaviours, like prevention, avoidance or moving away.

The remainder of the paper proceeds as follows. Section 2 briefly sketches the existing approaches to the income-related equity issue relevant to non-market valuation, and introduces subsistence needs. Section 3 describes the relevant models and proposes a simple adjustment factor. Section 4 analyses the impacts of subsistence needs on the monetary assessment of non-market goods: a lower valuation, a plutocratic partiality and potential ranking reversal. Section 5 presents an empirical illustration from Canadian and French income data. The discussion and conclusion are in Section 6.

2. Accounting for the income-related equity issue: a literature review

Pearce et al. (2006) remarked that WTP "is heavily influenced by ability to pay (income, wealth). The result is a cost-benefit rule for sanctioning or rejecting projects or policies that is biased in favour of those with higher incomes, raising issues of distributional fairness" (p. 31). Several approaches may help decision-makers tackle the ability to pay issue and better account for the non-market good preferences of the whole population.

2.1 Ability to pay

One strand of research attempts to capture inequalities in ability to pay through theoretical or empirical income-based corrections.

Instead of income, the use of discretionary income (i.e. the income above a level of committed expenditure on market goods) has been proposed in non-market valuation modelling. However, this is limited to theoretical models: McFadden and Leonard (1993) use discretionary income up to the compensating variation function, subsequently explicitly using income in the remainder of their paper, and Carson and Czajkowski (2014) quickly abandon discretionary income on the grounds that it carries considerable measurement error, which is likely to bias the coefficient estimates. The only noticeable exception we found is an empirical study exploring the effects of a mental accounts-type treatment. Li et al. (2005a,b) use additional reminders about the discretionary income of respondents and its use for environmental causes, and find significant budget constraint effects, although the joint additional reminders make disentangling the income effect difficult.

From an empirical perspective, a few authors tackle the ability-to-pay issue through *ex ante* or *ex post* methods. Donaldson (1999), for instance, proposes an *ex post* weighting of individual WTP defined as the ratio of the sample average of incomes to individual income at a given power, the elasticity of the marginal utility of income. This is assumed to help account for inequality aversion. Although the ranking did not change under no or different weightings, he concludes that WTP reflects not only strength of preferences but also ability to pay, which is problematic when preferences are correlated with income.

In SP surveys, Chanel et al. (2013) use an *ex ante* approach with normalised scenarios involving a given (hypothetical) income assumed equal for everyone, and compare them to standard scenarios. They exploit the differences to adjust WTP, which leads to a 20% increase in standard WTP on average. Shono et al. (2014) explore whether individuals are actually able to pay the amount they declare. They use an *ex ante* approach to assess two WTPs: "standard" WTP as well as the maximum price respondents can pay without resorting to debt (referred to as "payable"). In their empirical study on three health services, they find a higher demand curve for standard WTP than for payable WTP (from 15.4% to 70.8%). In addition, the gap is negatively affected by income and larger for the poorest for one of these health services.

Breffle et al. (2015) collect WTP *ex ante* through a specific design and derive an equity adjustment factor, applied *ex post*. They consider three programs, two independent and one combining the two others, and establish that income effects should make the WTP for the combined program lower than the sum of WTP for the two others. Because this income effect is expected to be larger for the poorest than for the richest, they exploit this difference on the combined program to build a partially equity-adjusted WTP. When applied to the combined program of the poorest, it leads to a WTP increase of about 13%.

Overall, the above approaches tackle the ability-to-pay issue either from a theoretical perspective, using an *ex ante* specific design with non-monetary contributions or purposely-collected WTP, or through subjective *ex post* corrections without consensus.

2.2 Distributional weights

A second strand of research, frequent in the normative interpretation of CBA, uses *ex post* distributional weights. It computes the change in social welfare associated with a project (potentially including non-market goods) by applying distributional weights, representing the social marginal utility of income to individual WTP (see Johansson and Kriström, 2018; Fleurbaey et al., 2013). According to Fleurbaey et al. (2013), there are two main approaches available to estimate distributional weights: welfarist and non-welfarist.

The welfarist approach estimates the two components of the social marginal utility of income separately: the individual's marginal utility of income, and the weight attributed to every individual in the SWF. Whereas the former only depends on the characteristics of the individual utility function, the latter depends in addition on the choice of SWF, with a parameter that stands for aversion to inequality. Among the many, generally non-independent, sources of inequalities in a population, income and (to a lesser extent) health status are those most frequently taken into account. To avoid choosing an SWF, practitioners sometimes directly specify the social marginal utility of income, generally a function of income alone (Donaldson, 1999; Samson et al., 2018; Treasury, 2018). However, there is no consensus on how to set its parameters (Brent, 2006; Johansson and Kriström, 2018).

The non-welfarist approach directly estimates the social marginal utility of income in monetary terms, which requires tricky interpersonal comparison of utilities (Adler, 2016; Fleurbaey and Abi-Rafeh, 2016). This can be achieved through the equivalent income approach based on the fairness principle: survey respondents are asked to give their preferences on different combinations of resources (Fleurbaey et al., 2013; Samson et al., 2018). The subjective well-being approach can also be used to compare individuals' emotions, feelings or life satisfaction and derive distributional weights (see Fleurbaey and Abi-Rafeh, 2016; Bronsteen et al., 2013; for a discussion). Although non-welfarist approaches are truly based on individual preferences, decision-makers almost never implement them in practice due to their complexity and the additional data required: they are good- and country-dependent, and require specific surveys.

Overall, the above approaches tackle the income-related equity issue by requiring specific surveys to directly elicit individual preferences, or explicit subjective judgments on the interpersonal comparison of utilities. As pointed out by Hammitt (2021), all approaches "depend on normative choices that are fundamentally equivalent judgments about how to evaluate improvements to some people and harms to others" (p. 16). We propose below an approach that offers an *ex post* alternative to account for the impact of differences in income on non-market preference revelation, simple to implement, and that relies on subsistence needs.

2.3. Subsistence needs

The concept of subsistence needs is based on the works of the psychologist Maslow (1943) and the economist Georgescu-Roegen (1954). It relies on the following hierarchy of needs (or wants), from the bottom upwards: physiological, safety, love and belonging, esteem, and self-actualisation. Strasnick (1981) noted two interesting points based on

Georgescu-Roegen (1954)'s approach. First, because each of the needs must be fulfilled before considering satisfying the next one, this "subordination of wants and satiable wants" leads to the principle of diminishing marginal utility. Second, the "irreducibility of wants" limits substitutability not only between needs, but also between goods for a given type of need (Stern, 1997).

Drawing on this framework, we consider that individuals start by satisfying their basic needs (referred to as subsistence needs) thanks to the minimum expenditure on food, water, energy, housing, clothes, transportation, etc. required to live in a given country. It is only when these subsistence needs are satisfied that individuals can consider more secondary needs (including non-market goods) by moving up in the hierarchy. This minimum level of subsistence needs is country-dependent, due to differences both in standard of living and in cultural construction (Sen, 1987). It is thus related to the recent concept of societal poverty (World Bank, 2018) accounting for the fact that needs increase with the wealth of a society to allow participation in that society with dignity. It also speaks to the long-standing debate on the impact of universal provision of subsistence (or basic) goods (Reinert, 2018), for instance through universal basic income (Van Parijs and Vanderborght, 2017), currently revitalised by the COVID-19 pandemic.

Consequently, when individuals state their WTP for non-market goods, in revealed or SP methods, they rely on substitutability between market goods and non-market goods depending on their preferences, but consider that there is a minimum level of market goods corresponding to the fulfillment of subsistence needs. This differs from the approaches based on discretionary income or ability to pay, which already embed preferences for market goods leading to various levels of consumption.

As far as we know, no study to date has explored how individual subsistence needs impact WTP for non-market goods. Yet economists have long applied the concept of subsistence requirements, in ecological economics for natural resources (Shyamsundar and Kramer, 1996; Thompson et al., 2017; Shrestha et al., 2006) or ecosystem services (Baumgärtner et al., 2017b; Drupp, 2018). In non-market valuation, subsistence requirements have been applied to lexicographic preferences between market and non-market goods (Stevens et al., 1991; Veisten et al., 2006; Rekola, 2003) or used to discuss the limits to substitution between them (cf. a thorough albeit old presentation in Stern, 1997)

3. Models

Below, we detail the standard model and the model incorporating subsistence needs based on a Constant Elasticity of Substitution (CES) utility function, determine the WTPs and propose a subsistence-needs adjustment factor.

3.1. Defining the two utility models under a CES function

3.1.1. Standard model under a general utility function

Consider an individual i whose preference relation is continuous, monotonic and convex. Let us consider that this preference relation is represented by a utility function $u_i(x_i, q_{i,j})$, where x_i represents the quantity of a composite market good and $q_{i,j}$ the quantity of non-market goods, $j = 1, ..., J$, associated with a project. $u_i(x_i, q_{i,j})$ is assumed to be twice continuously differentiable, strictly increasing and strictly quasi-concave in x_i and $q_{i,j}$, with $x_i, q_{i,j} \geq 0$. The individual budget constraint is $px_i = y_i$, i.e. all his/her income y_i is spent on the composite market good at price p,[1] and $q_{i,j}$ is considered exogenous to the individual (see Horowitz et al., 2013; Dupoux and Martinet, 2019).

We are interested in the relation between the WTP for the non-market goods and the individual's income. We follow the main trend in the literature on non-market valuation (Hanemann, 1991; Lankford, 1988; Ebert, 2003) by defining the marginal WTP as the Lindahl or virtual price for $q_{i,j}$:

$$WTP_{i,j}(p, q_{i,j}, y_i) = \frac{\partial v_i(p, q_{i,j}, y_i)/\partial q_{i,j}}{\partial v_i(p, q_{i,j}, y_i)/\partial y_i} \quad (1)$$

where $v_i(p, q_{i,j}, y_i)$ is the indirect utility function obtained from the standard maximization problem. $WTP_{i,j}$ represents the change in income that compensates for the change in the non-market good j. It only depends on the individual's preferences represented by the parameters characterising $v_i(.)$, quantities of non-market goods $q_{i,j}$, p and income y_i. Since we consider that an individual spends all his/her income on market goods, we set $x_i \equiv y_i/p$ and $p \equiv 1$ (without loss of generality in a static framework) in the following. Thus, composite market good x_i can be seen as the numéraire representing the individual's income.

3.1.2. Standard model under a CES utility function

To determine the explicit relationships between the standard and the subsistence needs frameworks, we need to start from a functional form that is as flexible as possible regarding preferences. A relevant, easy to interpret, tractable and well-known specification of the

[1] We restrict to small projects unable to markedly change relative prices of goods or real income, to avoid inconsistencies (Brent, 2006; Boadway, 1974; Blackorby and Donaldson, 1990).

utility function in consumer theory is the CES function first proposed by Arrow et al. (1961) and extensively used since then in environmental economics (see for instance Ebert, 2003; Sterner and Persson, 2008; Baumgärtner et al., 2017b; Drupp, 2018; Dupoux and Martinet, 2019; Meya, 2020). For $J+1$ goods and a given individual i it is:

$$u_i(x_{i,k}) = [\sum_k \alpha_{i,k} x_{i,k}^{\theta_i}]^{\frac{1}{\theta_i}} \text{ for } \theta_i \in]-\infty; 1] \ ; 0 < \alpha_{i,k} < 1 \ ; \sum_k \alpha_{i,k} \equiv 1 \ ; k = 0, ..., J; \forall i \quad (2)$$

where $x_{i,k}$ is the quantity of good k, $\alpha_{i,k}$ its share parameter and $1/(1-\theta_i)$ the elasticity of substitution. Note that the CES function covers a range from perfect complement ($\theta_i \to -\infty$) to perfect substitute ($\theta_i \to 1$), as well as the Cobb Douglas function ($\theta_i \to 0$).[2]

WTP are defined as in Eq.(1), but based on $u_i(x_{i,k}) = u_i(x_i, q_{i,j})$, where $x_i \equiv x_{i,0}$ stands for the quantity of composite good / income, and $q_{i,j} \equiv x_{i,j}, j = 1, ..., J$ stands for the quantities of non-market goods.

3.1.3. Model with subsistence needs under a CES function

Let us consider that individuals face minimum subsistence needs defined by level of consumption x_s of the composite good. Below the minimum subsistence needs, nobody is willing to trade the composite good for non-market goods, because basic needs must be fulfilled first. This implies that $WTP_{i,j}$ is set at 0. Above the minimum subsistence needs, $WTP_{i,j}$ is defined as in the standard CES utility model but based on the $u_i^s(x_i - x_s, q_{i,j})$ function that accounts for these subsistence needs.[3]

3.2. Defining the WTPs under a CES utility function

3.2.1 Case of one non-market good (J=1)

The preferences over x_i and $q_{i,1}$ are expressed in a CES as follows:

$$u_i(x_i, q_{i,1}) = [\alpha_i x_i^{\theta_i} + (1-\alpha_i) q_{i,1}^{\theta_i}]^{\frac{1}{\theta_i}} \text{ for } \theta_i \in]-\infty; 1] \ ; 0 < \alpha_i < 1; \forall i \quad (3)$$

where α_i represents the preference for market good x_i relative to the preference for non-market good $q_{i,1}$.

At equilibrium, the WTP for the non-market good in the standard CES model is (from

[2] Indeed, $u_i(x_{i,k}) \to \prod_k x_{i,k}^{\alpha_{i,k}}$ when $\theta_i \to 0$.

[3] The rationale can be found in the discretionary income (see section 2.1) or in models that take into account minimum levels of consumption (known as "Stone-Geary" functions, after Geary, 1950; and Stone, 1954).

Eq. (1) and Eq. (3)):

$$WTP_{i,1} = \frac{\partial u_i(.)/\partial q_{i,1}}{\partial u_i(.)/\partial x_i} = \frac{(1-\alpha_i)q_{i,1}^{\theta_i - 1}}{\alpha_i x_i^{\theta_i - 1}} \tag{4}$$

We extend the CES function to account for minimum subsistence needs as follows:

$$u_i^s(x_i - x_s, q_{i,1}) = [\alpha_i(x_i - x_s)^{\theta_i} + (1-\alpha_i)q_{i,1}^{\theta_i}]^{\frac{1}{\theta_i}} \quad \text{for} \quad x_i > x_s; \quad \theta_i \in]-\infty; 1]; \;\; 0 < \alpha_i < 1; \forall i \tag{5}$$

The WTP for $q_{i,1}$ in the CES model with subsistence needs is (from Eq.(1) and Eq.(5)):

$$WTP_{i,1}^s = \frac{\partial u_i^s(.)/\partial q_{i,1}}{\partial u_i^s(.)/\partial x_i} = \frac{(1-\alpha_i)q_{i,1}^{\theta_i - 1}}{\alpha_i (x_i - x_s)^{\theta_i - 1}} \tag{6}$$

It is clear that observed $WTP_{i,1}^s$, when individuals face minimum subsistence needs, are always lower than $WTP_{i,1}$, except when $x_s = 0$, in which case $WTP_{i,1}^s \equiv WTP_{i,1}$.

3.2.2. Case of two non-market goods (J=2)

We extend the individual CES function in Eq. (3) to the case of two non-market goods, with quantity $q_{i,1}$ and $q_{i,2}$:

$$u_i(x_i, q_{i,1}, q_{i,2}) = \left(\alpha_{i,0}x^{\theta_i} + \alpha_{i,1}q_{i,1}^{\theta_i} + \alpha_{i,2}q_{i,2}^{\theta_i}\right)^{1/\theta_i} \tag{7}$$

with $\alpha_{i,0}$ the preference for the composite market good, $\alpha_{i,1}$ and $\alpha_{i,2}$ respectively the preferences for the first and second non-market goods, and $\alpha_{i,0} + \alpha_{i,1} + \alpha_{i,2} \equiv 1 \; \forall i$. The WTPs for the two non-market goods are respectively:

$$WTP_{i,1} = \frac{\partial u_i(.)/\partial q_{i,1}}{\partial u_i(.)/\partial x_i} = \frac{\alpha_{i,1}}{\alpha_{i,0}}\left(\frac{q_{i,1}}{x_i}\right)^{\theta_i - 1} \quad \text{and} \quad WTP_{i,2} = \frac{\partial u_i(.)/\partial q_{i,2}}{\partial u_i(.)/\partial x_i} = \frac{\alpha_{i,2}}{\alpha_{i,0}}\left(\frac{q_{i,2}}{x_i}\right)^{\theta_i - 1} \tag{8}$$

Extending the CES function similarly to Eq. (5) leads to:

$$WTP_{i,1}^s = \frac{\alpha_{i,1}}{\alpha_{i,0}}\left(\frac{q_{i,1}}{x_i - x_s}\right)^{\theta_i - 1} \quad \text{and} \quad WTP_{i,2}^s = \frac{\alpha_{i,2}}{\alpha_{i,0}}\left(\frac{q_{i,2}}{x_i - x_s}\right)^{\theta_i - 1} \tag{9}$$

As with one non-market good, observed $WTP_{i,.}^s$, when facing minimum subsistence needs, are always lower than $WTP_{i,.}$, except when $x_s = 0$.

3.3. Deriving a subsistence-needs adjustment factor

What we are looking for is the (unobserved) WTP that an individual endowed with the same preferences and the same income would have if her ability to pay equalled her entire income. That is, the practical individual subsistence-needs adjustment factor Z_i that makes the observed WTP_i^s (when facing minimum subsistence needs) equal to WTP_i (i.e., $Z_i WTP_i^s = WTP_i$):

$$Z_i = \frac{WTP_i}{WTP_i^s} = \frac{\frac{(1-\alpha_i)q^{\theta_i - 1}}{\alpha_i x_i^{\theta_i - 1}}}{\frac{(1-\alpha_i)q^{\theta_i - 1}}{\alpha_i (x_i - x_s)^{\theta_i - 1}}} = \left(\frac{x_i - x_s}{x_i}\right)^{\theta_i - 1} \tag{10}$$

Note that Z_i does not depend on preferences for the market good α_i and is proportionally larger for those who have a smaller income (due to the homothety of the CES). In the case of two non-market goods, it is clear from Eq. (8) and (9) that Z_i is also defined as above for each non-market good.

Z_i relies on a country-specific minimum level of subsistence needs and a very flexible utility function, which are indeed normative choices, but is characterized by parameters θ (a non-market-good-specific substitutability) and x_s, exogenous to both the individual and the decision-maker. It also relies on a country-specific distribution of income. Consequently, in a value transfer procedure, transferring mean observed WTPs from a study site (indexed by S) to a policy site (indexed by P) may account for differences between the sites, as follows:

$$E(WTP^{s,P}) = E(WTP^{s,S}) \left[\frac{E(x^P - x_s^P)}{E(x^S - x_s^S)}\right]^{\eta} \tag{11}$$

where η is the income elasticity of WTP, which, in a CES, is equal to 1-θ (cf. Meya et al., 2021).

Overall, we propose a simple and practical way to account for the impact of differences in ability to pay on WTP elicitation. This adjustment factor Z_i is only meant to account for the impact of subsistence needs on non-market valuation and is to be separated from the approaches sometimes used under a normative interpretation of CBA to account for health, economic or social inequalities. Consequently, it does not preclude additional equity-based adjustments using distributional weights or an SWF.[4]

4. Impacts of subsistence needs on decision-making

We explore how the subsistence needs issue impacts the WTPs of non-market goods (defined in section 3.2) as well as the outcomes of decision-making when income changes. The closer Z_i is to 1, the smaller the adjustment required to account for subsistence needs. We consider first how the average WTP assessed for a given project is affected

[4] Note that WTP_i can also be theoretically obtained with appropriate distribution weights based on a utilitarian SWF (see Appendix A).

when preferences are homogeneous over individuals (i.e. same α) and characterise the plutocratic partiality when they are heterogeneous between income groups (i.e. different α). Then we consider how relative project rankings are affected when preferences are heterogeneous.

4.1. Homogeneous preferences for one non-market good

When preferences are homogeneous over the population, accounting for minimum subsistence level leads to increased WTP. The size of this increase will depend on the actual distribution of income in the population (see applications to Canada and France in section 5)

Figure 1 illustrates the magnitude of adjustment factor Z_i for different combinations of θ and income (represented in terms of x/x_s). It can be seen that the lower the income, the higher Z_i for any given value of θ, due to the fact that WTP_i^s tends towards zero when income tends towards x_s. For an income seven times larger than x_s, for instance, the adjustment factor is about 1.26 (i.e. a 26% increase in WTP) when θ exhibits complementarity ($\theta = -0.5$), but only about 1.08 for substitutability ($\theta = 0.5$). This means that, at the aggregate level, the monetary assessment of projects including this non-market good will be increased *ceteris paribus* when adjustment factor Z_i is applied to account for subsistence needs.

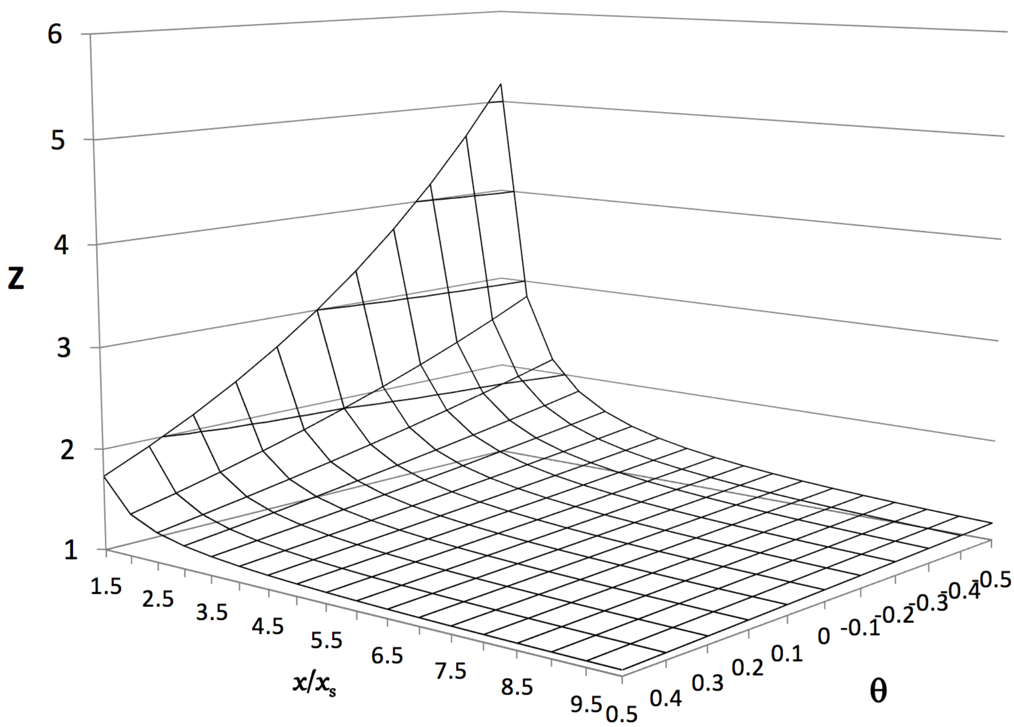
4.2. Heterogeneous preferences for one non-market good

When preferences regarding the non-market good are heterogeneous (i.e. vary over income groups), accounting for subsistence needs also increases the WTP, but the adjustment factor Z_i has a greater upward impact on WTP for the poorest fraction of the population than for the richest. This implies that without adjustment, the preferences of the richest will be better represented than those of the poorest whatever they are, a kind of plutocratic partiality.

As an illustration, imagine a population with a bi-modal income distribution (for the sake of simplicity): M individuals have a low income ($x_L = 1.5$ times subsistence needs), and N individuals have a high income ($x_H = 10$ times subsistence needs).[5] Let us consider that the preferences of the two subpopulations regarding the non-market good are respectively measured by α_L for the poorest and α_H for the richest, varying by stepsize

[5] The generalisation to more income groups in a discrete or continuous way is straightforward but would make the graphic representation less intuitive. See for instance Baumgärtner et al. (2017a) or Meya (2020), who use a log-normally distributed income with a CES function in a continuous framework.

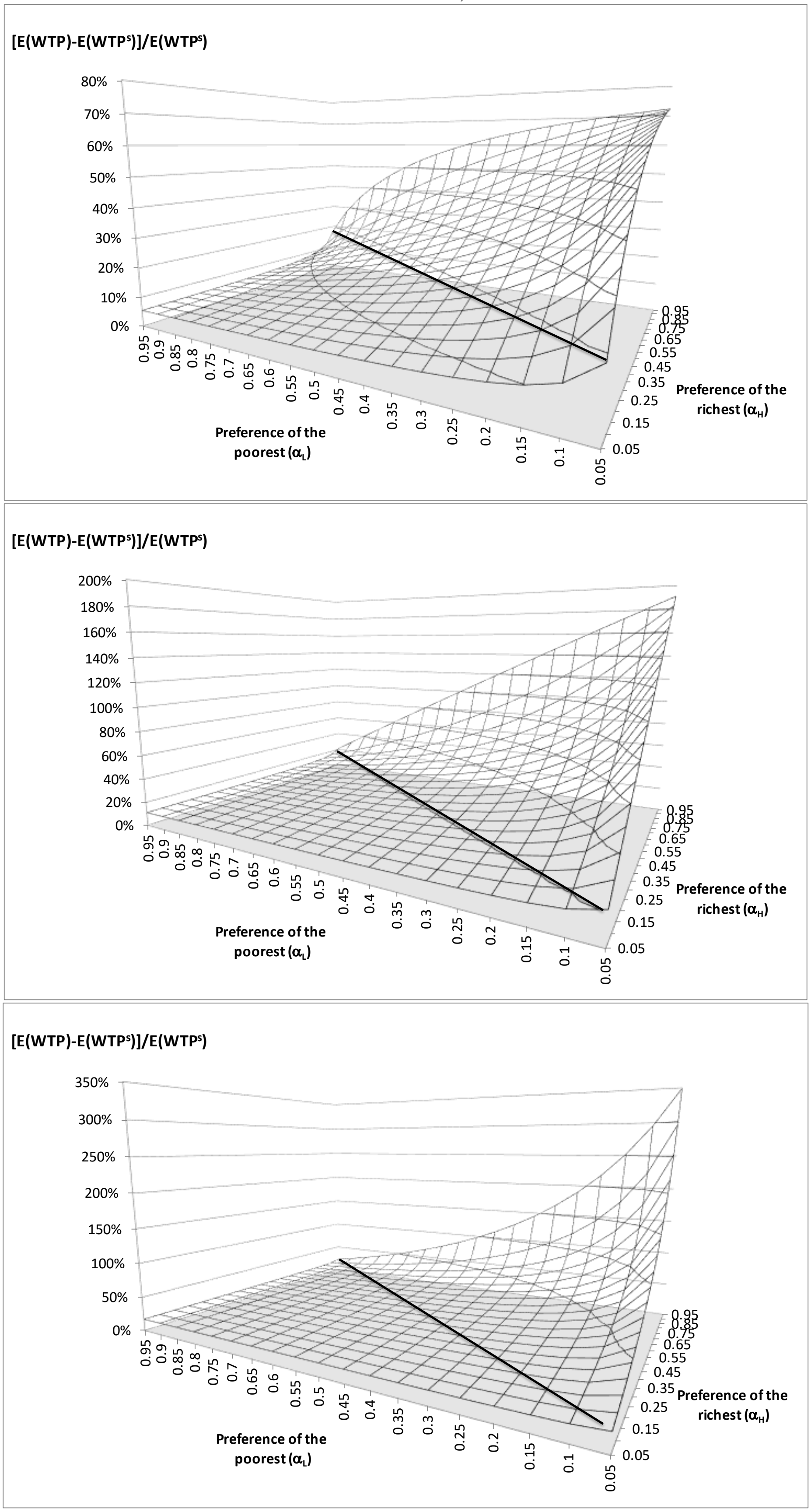
Figure 1: Adjustment factor Z_i when preferences are homogeneous (by θ and income relative to x_s)



.05, from .05 (strong preference for the non-market good) to .95 (strong preference for the market good). The WTPs for each group of income are WTP_L, and WTP_H, and the mean WTPs in the population are $E(WTP^s) = (M+N)^{-1}[MWTP_L^s + NWTP_H^s]$ without adjustment, and $E(WTP) = (M+N)^{-1}[MWTP_L + NWTP_H]$ after adjustment. We compute and represent $[E(WTP) - E(WTP^s)]/E(WTP^s)$, the relative change in mean WTP when subsistence needs are accounted for, for three values of substitutability ($\theta = 0.5, 0, -0.5$) in Figure 2, for $M = N$. The closer to 0, the lower the impact of subsistence needs on the population's non-market monetary assessment.

Whatever the substitutability value θ, we have the following results. For homogeneous preferences (represented by the diagonal black line segment on the three figures), the adjustment factor is clearly constant, with a relative change of about 20%. Provided the preferences of the richest are more non-market oriented than those of the poorest (to the left of the diagonal), the relative change is smaller than in the homogeneous case. The preferences of the richest (for the non-market good) are favoured, because the WTP for the non-market good requires less adjustment to account for subsistence needs. Provided the preferences of the richest are less non-market oriented than those of the poorest (to the right of the diagonal), the relative change is larger than in the homogeneous case.

Figure 2: Average adjustment factor when preferences are heterogeneous (upper panel: $\theta = .5$, middle panel: $\theta = 0$, lower panel: $\theta = -.5$)



The preferences of the richest (now for the market good) are favoured again, because more adjustment is required. Note that when the number of the poorest differs from the number of the richest, the previous results still hold, the average adjustment factor being higher when $M > N$ and lower when $N > M$, *ceteris paribus*.

Overall, whatever the preferences of the richest, they are always better represented in the monetary assessment of a project involving a non-market good than those of the poorest, a kind of plutocratic partiality. In particular, the non-market preferences of the poorest appear never to be properly accounted for unless shared by the richest (i.e. the homogenous case), whereas the non-market preferences of the richest are unfailingly better accounted for, for two reasons. First, their WTPs are higher. Second, their WTPs are also less affected by the subsistence needs: the parts of Figure 2 to the left of the diagonal are always closer to 0 than those to the right. This second fact explains why applying the adjustment factor Z_i accounts for the plutocratic partiality.

4.3. Heterogeneous preferences for two non-market goods

We will now consider how the issue of subsistence needs may affect the ranking of two projects with different (levels of) non-market goods. If preferences are homogeneous among income groups, there cannot be ranking reversal by definition, because everyone will prefer the same project. However, in the heterogeneous case, there may be ranking reversal between projects depending on whether or not the monetary assessment includes the subsistence-needs adjustment factor. We consider two projects (A and B)[6] and introduce heterogeneity in preferences for non-market goods as before, by considering a population composed of N individuals with a high income (with preferences $\alpha_{H,A}$ and $\alpha_{H,B}$) and M individuals with a low income ($\alpha_{L,A}$ and $\alpha_{L,B}$, with $\alpha_0 + \alpha_{H,A} + \alpha_{H,B} \equiv 1$ and $\alpha_0 + \alpha_{L,A} + \alpha_{L,B} \equiv 1$).

Ranking reversal only occurs if the following condition is fulfilled (see proof in Appendix B):

$$1-\alpha_0-\frac{N}{M}\left(\frac{x_H-x_s}{x_L-x_s}\right)^{1-\theta}(1-\alpha_0-2\alpha_{H,A}) > 2\alpha_{L,B} > 1-\alpha_0-\frac{N}{M}\left(\frac{x_H}{x_L}\right)^{1-\theta}(1-\alpha_0-2\alpha_{H,A})$$

Figure 3 (and C1 and C2 in Appendix C) represents this condition in terms of $\alpha_{H,A}$ and $\alpha_{L,B}$ for three values of θ, and as a function of α_0. For convenience and ease of comparison with previous results, we set as previously x_L at 1.5 times subsistence needs, and x_H at 10

[6] To avoid adding complexity, we assume that the non-market goods of the two projects are different. Otherwise, a function accounting for the proportion of the two goods in each project would be required.

times subsistence needs. On the X-axis, we measure $\alpha_{H,A}$, the preference for project A of the high-income individuals: the closer to $(1 - \alpha_0)$, the stronger this preference, whereas the closer to 0, the stronger the preference for project B, while $(1 - \alpha_0)/2$ indicates indifference between the two projects (i.e. $\alpha_{H,A} = \alpha_{H,B}$). On the Y-axis, we measure $\alpha_{L,B}$, the preference for project B of the low-income individuals: the closer to $(1 - \alpha_0)$, the stronger this preference, whereas the closer to 0, the stronger the preference for project A, with indifference at $(1 - \alpha_0)/2 = \alpha_{L,A} = \alpha_{L,B}$.

Each figure is composed of four quadrants. Interpretation of the figures does not depend on θ, nor on the income distribution.

In quadrants 1 and 4, no ranking reversal is observed since individuals with both low and high incomes prefer the same project (project B in quadrant 1 (cases A-Ia and B-IIa in Appendix B) and project A in quadrant 4 (cases A-IIa and B-Ia in Appendix B)), although to varying degrees.

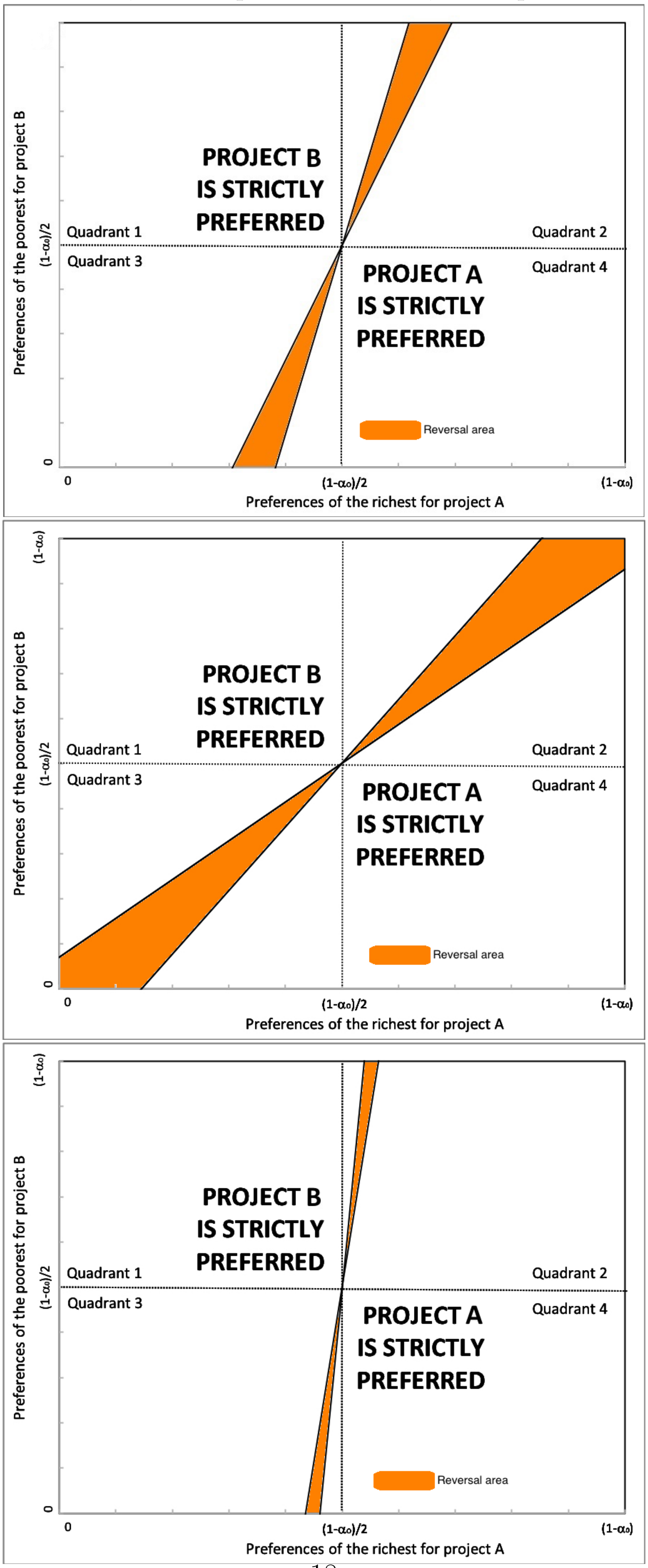
In quadrant 2, the low-income individuals prefer project B while the high-income individuals prefer project A (the 45° line represents a similar respective degree of preference). The area above the ranking reversal area represents the pattern arising from the combined preferences of high- and low-income individuals: a preference for project B. The area below it represents the pattern of preference for project A. The ranking reversal area represents combinations of preferences for which project A is preferred based on subsistence-needs-adjusted WTP whereas project B is preferred based on observed WTP (case B-Ib in Appendix A): the preferences of high-income individuals are favoured in the absence of adjustment.

Quadrant 3 shows a similar situation, with low-income individuals preferring project A and high-income individuals project B. The ranking reversal area now represents a pattern of preference for project B based on subsistence-needs-adjusted WTP and preference for project A based on observed WTP (caseA-Ib in Appendix B): the preferences of high-income individuals are again favoured in the absence of adjustment.

Figure 3 represents the case where $\theta = 0.5$ for different income distributions in the population ($M = N$, $M = 3N$ and $N = 3M$).

We observe that when $M = N$ (Figure 3(a)), the area of ranking reversal is below the 45° line in quadrant 3 (and above it in quadrant 2), which confirms the previous finding that high-income individuals' preferences (for project B in quadrant 3 and project A in quadrant 2) dominate those of low-income individuals (for project A in quadrant 3 and project B in quadrant 2) when WTP is not adjusted for subsistence needs, i.e. there is a

Figure 3: Pattern of preferences leading to ranking reversal between two projects when $\theta = .5$ (upper panel: $N = M$, middle panel: $M = 3N$, lower panel: $N = 3M$)



plutocratic partiality.
When there are three times more low incomes than high incomes ($M = 3N$, Figure 3(b)), areas of the poorest individuals' preferred project grow and cross the 45° line: the number effect makes it more likely that their preferred project will be chosen, although the subsistence-needs effect still favours the richest. There is still a ranking reversal area, which grows.
Finally, when there are three times more high incomes than low incomes ($N = 3M$, Figure 3(c)), the number effect reinforces the dominance of the richest individuals' preferences so that there is almost no room for the preferences of the poorest, and ranking reversal areas, albeit limited, are still observed.

The cases where $\theta = -0.5$ (complementarity) and $\theta = 0$ are shown in Appendix C. All previous results hold. A decrease in θ - the substitutability between the composite market good and the non-market goods - leads to decreased likelihood of the poorest individuals' preferences dominating, as well as to smaller ranking reversal areas. The preferences of the richest become increasingly likely to dominate as substitutability decreases and/or their proportion in the population increases.

Overall, we find that the subsistence-needs issue when a population's preferences are heterogeneous creates the conditions for ranking reversal between two projects, always with a bias towards the richest individuals' preferences, whatever they are.

5. Empirical illustrations

5.1. Data

We use real data to examine the extent to which the subsistence needs issue might affect the monetary assessment of non-market goods and value transfer procedures. We rely both on country-specific data for income and the cost of meeting subsistence needs (in Canada and France) expressed in 2016 euros, and on empirical studies eliciting elasticities of substitution for various non-market goods.

Regarding the distribution of income, we compute the distribution of annual (disposable) income by unit of consumption[7] for Canada (Statistics Canada, 2019) and France (Institut National de la Statistique et des Etudes Economiques, 2018), see the first part

[7] We use the OECD-modified scale to calculate equivalised disposable income per unit of consumption. This scale assigns a value of 1 to the household head, of 0.5 to each additional adult member and of 0.3 to each child below 14.

of Table 1. The average income by unit of consumption unit is €27,307 for Canada and €25,030 for France. We then have to set the cost of meeting subsistence needs x_s. For Canada, we rely on income supports covering basic expenses for individuals and families in the province of Alberta (AlbertaWorks, 2016), including food, clothing, household and personal needs, transportation and private housing expenses. The monthly core benefits for one single adult expected to work, living in private housing, was $CA627 in 2016 (€439). A French survey estimates the cost of subsistence needs to be about €600 per month for one adult in 2016 (Carrefour des Solidarités, 2011), which is comparable to the active solidarity revenue (RSA) paid by the French government to a single individual with no resources (€545 per month in 2017, in addition to aid for housing, public transport and a free health care scheme). We therefore adopt as a reasonable benchmark an annual cost of meeting subsistence needs per individual of €439x12 = €5,268 for Canada, and €600x12 = €7,200 for France. The distributions of annual income by unit of consumption are given in the first part of Table 1.

Regarding the substitutability of market goods for non-market goods, we merge data from Drupp (2018) and Drupp and Hänsel (2021), who gather θ estimates for various environmental non-market goods (air or water quality improvements, forest or marine services, landscape or recreational amenities, biodiversity, etc.) in different countries. We obtain 28 values in the range $[-.42; .90]$, with a mean empirical estimate of $\theta = .48$ and a standard deviation of .34. This means that, on average, individuals exhibit substitutability between market goods and non-market goods. According to our results in section 4, the subsistence-needs adjustment factor would be lower *ceteris paribus* than for complementarity, although there would be room for ranking reversal between projects. Results in Table 1 are presented for three values of θ: mean (0.48), and -/+ 1 standard deviation around the mean, i.e. .14 and .82.

5.2. Comparing monetary assessments of a non-market good

We assume that preferences regarding the non-market good are homogeneous over income groups, since we lack relevant data on the population's actual distribution of preferences for the non-market good w.r.t. income. The second part of Table 1 represents the subsistence-needs adjustment factor Z by country and values of θ, and for various levels of income (remember from section 3, that Z does not depend on α in the homogeneous case). Within a given country, the adjustment factor decreases with income and decreases with the substitutability parameter θ, as expected. Between countries, we find larger adjustment factors for France than for Canada at any given income level, due to the difference

Table 1: Subsistence-needs adjustment factor Z in the French population, by θ

Income classes by unit of consumption (1)	**Distribution of income (2)**		**Subsistence-needs adjustment factor Z (3)**					
	Canada	**France**	**Study site: Canada**			**Study site: France**		
(in €)	(in %)	(in %)	θ=.82	θ=.48	θ=.14	θ=.82	θ=.48	θ=.14
Less than 5,268	5%	2.9%	–	–	–	–	–	–
5,268 to 7,200	3.3%	4.2%	1.399	2.637	4.971	–	–	–
7,200 to 10,000	6.9%	3.4%	1.186	1.637	2.260	1.386	2.570	4.764
10 to 15,000	13.5%	12.3%	1.104	1.329	1.601	1.167	1.562	2.092
15 to 20,000	14.2%	25.1%	1.067	1.205	1.361	1.100	1.317	1.578
20 to 25,000	13.2%	18.3%	1.049	1.149	1.258	1.072	1.222	1.393
25 to 30,000	11.4%	12.1%	1.039	1.117	1.201	1.056	1.171	1.298
30 to 35,000	9.0%	5.3%	1.032	1.096	1.164	1.046	1.139	1.240
35 to 40,000	6.6%	3.6%	1.028	1.082	1.139	1.039	1.117	1.201
40 to 45,000	4.3%	3.1%	1.024	1.071	1.121	1.034	1.101	1.173
45 to 50,000	2.6%	1.9%	1.021	1.063	1.106	1.030	1.089	1.152
50 to 55,000	1.4%	1.4%	1.019	1.057	1.095	1.027	1.080	1.135
55 to 60,000	0.8%	0.6%	1.017	1.051	1.086	1.024	1.072	1.122
60 to 65,000	0.8%	0.8%	1.016	1.047	1.079	1.022	1.066	1.111
65 to 70,000	1.2%	0.8%	1.015	1.043	1.072	1.021	1.060	1.102
70 to 75,000	1.8%	2.8%	1.014	1.040	1.067	1.019	1.056	1.094
75 to 80,000	2.3%	0.5%	1.013	1.037	1.062	1.018	1.052	1.087
80,000 plus	1.8%	1.0%	1.008	1.024	1.039	1.011	1.033	1.055
(4) Mean WTP^s (€): (2)xWTP^s			**5.5**	**163**	**5,213**	**5.3**	**146**	**4,359**
(5) Mean WTP (€): (2)x(3)xWTP^s			**5.8**	**187**	**6,297**	**5.7**	**179**	**5,818**
(6) Change in Mean WTP (%): [(5)-(4)]/(4)			**6.1**	**14.9**	**20.8**	**8.3**	**22.3**	**33.5**
(7) True value transfer factor on mean WTP^s			**.955**	**.897**	**.836**	**1.047**	**1.115**	**1.196**
(8) Commonly-used value transfer factor for WTP^s			**.984**	**.956**	**.928**	**1.016**	**1.046**	**1.078**
(9) Adjusted value transfer factor for mean WTP^s			**.963**	**.896**	**.833**	**1.038**	**1.116**	**1.200**

Notes: In rows (4-5), WTP^s are based on Eq. (6), mid-values of income classes, q=1 and α=.5. In row (6), results on changes in mean WTP^s do not depend on q nor on α. In rows (7-9), the policy site is by convention the other country. In row (7), the true value transfer factors are computed as the ratio of the mean WTP^s for the policy site over the mean for the study site. In row (8), the value transfer factors are based on Eq. (12), and in row (9), on Eq. (11).

in the cost of meeting subsistence needs. We then compute the mean income-weighted WTP over the population without and with subsistence needs adjustment in rows (4) and (5) as well as the corresponding relative change in row (6). When $\theta = .48$ (respectively .14 and .82), the change in mean WTP is found to be 14.9% (respectively 6.1% and 20.8%) for Canada, and larger for France: 22.3% (respectively 8.3% and 33.5%). This is due to the additional effect of country differences in income distribution.

5.3. Comparing value transfer procedures

The subsistence needs-based adjustment factor we propose may have a role to play in value transfer procedures. We start from the commonly used formula for estimating the value transfer factor, which relies on the mean observed WTP from the study site, the mean income levels at both sites and the income elasticity of WTP (see Czajkowski et al., 2017; Meya et al., 2021):

$$E(WTP^{s,P}) = E(WTP^{s,S}) \left[\frac{E(x^P)}{E(x^S)}\right]^{\eta} \tag{12}$$

where η is the income elasticity of WTP and equal to $1 - \theta$.

In Table 1 row (7), we compute the true ratio of study site observed WTPs to those of the other (policy) site (the latter being computed thanks to Eq. (6) but unobserved during real value transfers). These values are higher (respectively lower) than 1 when the study site has a lower (respectively higher) mean income level than the policy site, and approach 1 when θ increases. In row (8), we compute the corresponding factor based on Eq (12) and observed WTP when $\theta = .48$ (respectively .14 and .82). We obtain .956 (respectively .984 and 928) when the transfer is from Canada to France, and 1.046 (respectively 1.016 and 1.078) when the transfer is from France to Canada. We can check that these factors are reasonably close to the figures in row (7), but bias towards 1.

Finally, in row (9), we compute the value transfer factors based on Eq. (11), i.e. accounting for the cost of meeting subsistence needs at the study and the policy sites. These factors differ from the commonly-used factors, but are much closer to the figures in row (8). Note that accounting for the subsistence-needs issue in value transfer can be done *ex post*, based on the Z distribution in the policy site.

Overall, we find that the value transfer factor accounting for subsistence needs performs better in predicting observed WTP at the policy site than the commonly-used factor, while requiring no additional data other than the cost of meeting subsistence needs in both sites.

6. Discussion

The monetary assessment of a project containing a non-market good is always driven by the preferences of the richest unless income-related equity is allowed for. This is true not only in absolute terms, but also in relative terms, when the population's preferences differ. Our findings show that incorporating a subsistence-needs adjustment factor is a simple and practical way of better accounting for the preferences of the poorest, without precluding the additional use of distributional weighting to tackle the equity and distributional issues. In many economic analyses, differences in the non-market values chosen to assess welfare change may lead to divergent conclusions (see for instance Sterner and Persson, 2008; on the economic impact of climate change).

Our work is subject to limitations. First, for the sake of interpretation and tractability, we chose to derive our subsistence-needs adjustment factor from one specific utility function. The CES was the best candidate: an absolutely standard and flexible function widely used in consumer theory that fits very different patterns of preferences. Second, what we propose is a way to better account for the non-market preferences of the whole population when comparing several projects under a positive interpretation of CBA. However, we lack a definitive normative justification for our adjustment factor, like any other adjustment method (Hammitt, 2021). All we can claim is that ours has the advantage of being exogenously based on country-specific and good-specific parameters, and of being applicable *ex post* to data already collected. Finally, within CBA, we are aware that the question of whether a given project will indeed pass a cost-benefit test once implemented applies to any adjustment factor. Actually, if the project is to be funded through individual contributions, there is no guarantee that the poorest will be able to contribute as much as they indicate through WTP, regardless of how it is adjusted.

Our findings have implications for empirical research in economics, in addition to raising policy issues.

From an empirical perspective, our findings challenge the use of revealed and SP techniques in CBA involving preferences for a non-market good and measured through WTP. When these preferences are homogeneous, the average preference of the population is properly accounted for. When these preferences depend on income group (or any other socio-demographic characteristics correlated with income, like education, place of residence or age), the preferences of the poorest individuals may be under-represented and those of the richest over-represented. Decision-makers should be aware of the plutocratic partiality issue and the possibility of project ranking reversal. The simple *ex post* adjustment factor we propose offers an initial guide adaptable to country-specific minimum subsistence needs and to any substitutability value of non-market goods.

Our findings also contribute to the body of research on international value transfer. Recent evidence suggests that transferring values through simple income adjustment (Czajkowski et al., 2017; Johnston et al., 2021; Meya et al., 2021) or income inequality adjustment (Baumgärtner et al., 2017a; Meya et al., 2021) may be as efficient as more complex adjustment through benefit functions. The adjustment factor we propose constitutes a utility-based alternative approach that accounts for country differences in both income and levels of subsistence needs, and whose performance w.r.t. existing value / function transfers deserves investigation. So too does its potential to account for differences in the type of non-market good that is the object of the value transfer (through different values for elasticity of substitution / income elasticity of WTP).

In terms of policy implications, our findings contribute to the equity vs. equality debate around whether WTP elicited from the poorest should be adjusted when preferences for a non-market good are known to depend on income groups. Doing so means choosing equity (an as-fair-as-possible representation of preferences) over equality (a common representation of preferences). How would public priorities be affected (see Olsen and Donaldson, 1998; for a discussion regarding health, where priorities depend on income or age)? What impact would a change in income inequality have on the assessment of a project? Baumgärtner et al. (2017a) and Meya et al. (2020) show that, depending on whether the non-market good is a substitute or a complement for manufactured goods, increased inequality can either decrease or increase mean WTP. Once non-market values are involved in decision-making, we need to be on the lookout for any potential plutocratic partiality or ranking reversal effect that may not be accounted for *ex post* by distributional weightings.

References

Adler, M. D. (2016). Benefit–Cost Analysis and Distributional Weights: An Overview. *Review of Environmental Economics and Policy*, 10(2):264–285.

Adler, M. D. (2019). *Measuring Social Welfare: An Introduction.* Oxford University Press, USA.

AlbertaWorks (2016). Financial Benefits Summary, Alberta Government, EMP0433 (2016/08). Technical report.

Arrow, K. J., Chenery, H. B., Minhas, B. S., and Solow, R. M. (1961). Capital-Labor Substitution and Economic Efficiency. *The Review of Economics and Statistics*, 43(3):225–250.

Atherton, J. (2019). *Capturing Public Views on Complex and Unfamiliar Goods: Chemical Water Pollution in England and Wales.* PhD thesis, The London School of Economics and Political Science (LSE).

Baumgärtner, S., Drupp, M. A., Meya, J. N., Munz, J. M., and Quaas, M. F. (2017a). Income Inequality and Willingness to Pay for Public Environmental Goods. *Journal of Environmental Economics and Management*, 85:35–61.

Baumgärtner, S., Drupp, M. A., and Quaas, M. F. (2017b). Subsistence, Substitutability and Sustainability in Consumption. *Environmental and Resource Economics*, 67(1):47–66.

Blackorby, C. and Donaldson, D. (1990). A Review Article: The Case against the Use of the Sum of Compensating Variations in Cost-Benefit Analysis. *The Canadian Journal of Economics*, 23(3):471–494.

Boadway, R. W. (1974). The Welfare Foundations of Cost-Benefit Analysis. *Economic Journal*, 84(336):926–939.

Breffle, W. S., Eiswerth, M. E., Muralidharan, D., and Thornton, J. (2015). Understanding How Income Influences Willingness to Pay for Joint Programs: A More Equitable Value Measure for the Less Wealthy. *Ecological Economics*, 109:17–25.

Brekke, K. A. (1997). The Numéraire Matters in Cost-Benefit Analysis. *Journal of Public Economics*, 64(1):117–123.

Brent, R. J. (2006). *Applied Cost–Benefit Analysis, Second Edition*. Edward Elgar Publishing.

Bronsteen, J., Buccafusco, C. J., and Masur, J. S. (2013). Well-Being Analysis vs. Cost-Benefit Analysis. *Duke Law Journal*, 62:1603–1689.

Carrefour des Solidarités (2011). Pour un Revenu Minimum de Survie. https://www.carrefourdessolidarites.org/Pour-un-Revenu-Minimum-de-Survie. Accessed 6 February 2019.

Carson, R. T. and Czajkowski, M. (2014). The Discrete Choice Experiment Approach to Environmental Contingent Valuation. In *Handbook of choice modelling*. Edward Elgar Publishing.

Chanel, O., Chichilnisky, G., Massoni, S., Vergnaud, J.-C., and Lyk-Jensen, S. V. (2013). Décision en Présence d'Incertitude et d'Émotions Face à des Risques de Catastrophes Naturelles (RISKEMOTION), Final Report ANR-08-RISKNAT-007-01, Greqam, Marseille, France.

Czajkowski, M., Ahtiainen, H., Artell, J., and Meyerhoff, J. (2017). Choosing a Functional Form for an International Benefit Transfer: Evidence from a Nine-Country Valuation Experiment. *Ecological Economics*, 134:104–113.

Donaldson, C. (1999). Valuing the Benefits of Publicly-Provided Health Care: Does 'Ability to Pay' Preclude the Use of 'Willingness to Pay'? *Social Science & Medicine*, 49(4):551–563.

Drupp, M. A. (2018). Limits to Substitution Between Ecosystem Services and Manufactured Goods and Implications for Social Discounting. *Environmental and Resource Economics*, 69(1):135–158.

Drupp, M. A. and Hänsel, M. C. (2021). Relative Prices and Climate Policy: How the Scarcity of Nonmarket Goods Drives Policy Evaluation. *American Economic Journal: Economic Policy*, 13(1):168–201.

Dupoux, M. and Martinet, V. (2019). Can the Environment be an Inferior Good? A Theory with Context-Dependent Substitutability and Needs. FAERE Working Paper, 2019.08.

Ebert, U. (2003). Environmental Goods and the Distribution of Income. *Environmental and Resource Economics*, 25(4):435–459.

Fleurbaey, M. and Abi-Rafeh, R. (2016). The Use of Distributional Weights in Benefit–Cost Analysis: Insights from Welfare Economics. *Review of Environmental Economics and Policy*, 10(2):286–307.

Fleurbaey, M., Luchini, S., Muller, C., and Schokkaert, E. (2013). Equivalent Income And Fair Evaluation Of Health Care. *Health Economics*, 22(6):711–729.

Geary, R. C. (1950). A Note on 'A Constant-Utility Index of the Cost of Living'. *The Review of Economic Studies*, 18(1):65–66.

Georgescu-Roegen, N. (1954). Choice, Expectations and Measurability. *The Quarterly Journal of Economics*, 68(4):503–534.

Hammitt, J. K. (2021). Accounting for the Distribution of Benefits and Costs in Benefit–Cost Analysis. *Journal of Benefit-Cost Analysis*, 12(1):64–84.

Hanemann, W. M. (1991). Willingness to Pay and Willingness to Accept: How Much Can They Differ? *The American Economic Review*, 81(3):635–647.

Horowitz, J. K., McConnell, K. E., and Murphy, J. (2013). Behavioral Foundations of Environmental Economics and Valuation. In List, J. and Price, M., editors, *Handbook on Experimental Economics and the Environment*, chapter 4, pages 115–156. Edward Elgar Publishing.

Institut National de la Statistique et des Etudes Economiques (2018). Revenu, niveau de vie et pauvreté en 2015. Enquête Revenus fiscaux et sociaux (ERFS) - Insee Résultats.

Johansson, P.-O. and Kriström, B. (2018). *Cost–Benefit Analysis*. Cambridge University Press, 1st edition.

Johnston, R. J., Boyle, K. J., Loureiro, M. L., Navrud, S., and Rolfe, J. (2021). Guidance to Enhance the Validity and Credibility of Environmental Benefit Transfers. *Environmental and Resource Economics*, 79:575–624.

Kassahun, H. T., Jacobsen, J. B., and Nicholson, C. F. (2020). Revisiting Money and Labor for Valuing Environmental Goods and Services in Developing Countries. *Ecological Economics*, 177:106771.

Lankford, R. H. (1988). Measuring Welfare Changes in Settings with Imposed Quantities. *Journal of Environmental Economics and Management*, 15(1):45–63.

Lee, J. (2016). Income and Distance-Decay effects on Willingness to Pay Estimated by the Contingent Valuation Method. *Journal of Environmental Planning and Management*, 59(11):1957–1981.

Li, H., Berrens, R. P., Bohara, A. K., Jenkins-Smith, H. C., Silva, C. L., and Weimer, D. L. (2005a). Testing for Budget Constraint Effects in a National Advisory Referendum Survey on the Kyoto Protocol. *Journal of Agricultural and Resource Economics*, 30(2):350–366.

Li, H., Berrens, R. P., Bohara, A. K., Jenkins-Smith, H. C., Silva, C. L., Weimer, D. L., et al. (2005b). Exploring the Beta Model Using Proportional Budget Information in a Contingent Valuation Study. *Economics Bulletin*, 17(8):1–9.

Maslow, A. H. (1943). A Theory of Human Motivation. *Psychological Review*, 50(4):370–396.

McFadden, D. and Leonard, G. (1993). Issues in the Contingent Valuation of Environmental Goods: Methodologies for Data Collection and Analysis. In Hausman, J., editor, *Contingent Valuation: A Critical Assessment*.

Meya, J. N. (2020). Environmental Inequality and Economic Valuation. *Environmental and Resource Economics*, 76:235–270.

Meya, J. N., Baumgärtner, S., Drupp, M. A., and Quaas, M. F. (2020). Inequality and the Value of Public Natural Capital, CESifo Working Paper Series 8752. Technical report.

Meya, J. N., Drupp, M. A., and Hanley, N. (2021). Testing Structural Benefit Transfer: The Role of Income Inequality. *Resource and Energy Economics*, 64:101217.

Mouter, N. (2019). The Politics of Cost-Benefit Analysis. In *Oxford Research Encyclopedia of Politics*.

Nyborg, K. (2014). Project Evaluation with Democratic Decision-Making: What Does Cost–Benefit Analysis Really Measure? *Ecological Economics*, 106:124–131.

OECD (2018). *Cost-Benefit Analysis and the Environment: Further Developments and Policy Use*. Organisation for Economic Co-operation and Development Publishing.

Olsen, J. A. and Donaldson, C. (1998). Helicopters, Hearts and Hips: Using Willingness to Pay to Set Priorities for Public Sector Health Care Programmes. *Social Science & Medicine*, 46(1):1–12.

Pearce, D. W., Atkinson, G., and Mourato, S. (2006). *Cost-Benefit Analysis and the Environment: Recent Developments*. Organisation for Economic Co-operation and Development, Paris.

Reinert, K. A. (2018). *No Small Hope: Towards the Universal Provision of Basic Goods*. Oxford University Press.

Rekola, M. (2003). Lexicographic Preferences in Contingent Valuation: A Theoretical Framework with Illustrations. *Land Economics*, 79(2):277–291.

Russell, S. (1996). Ability to Pay for Health Care: Concepts and Evidence. *Health Policy and Planning*, 11(3):219–237.

Sager, T. (2013). The Comprehensiveness Dilemma of Cost-Benefit Analysis. *European Journal of Transport and Infrastructure Research*, 13(3):169–183.

Samson, A.-L., Schokkaert, E., Thébaut, C., Dormont, B., Fleurbaey, M., Luchini, S., and Van de Voorde, C. (2018). Fairness in Cost-Benefit Analysis: A Methodology for Health Technology Assessment. *Health Economics*, 27(1):102–114.

Sen, A. (1987). *The Standard of Living.* Cambridge University Press, Cambridge. Tanner Lectures with rejoinders by Bernard Williams and others Italian translation: Marsilio, 1993.

Shono, A., Kondo, M., Ohmae, H., and Okubo, I. (2014). Willingness to Pay for Public Health Services in Rural Central Java, Indonesia: Methodological Considerations When Using the Contingent Valuation Method. *Social Science & Medicine*, 110:31–40.

Shrestha, R. K., Alavalapati, J. R., Seidl, A. F., Weber, K. E., and Suselo, T. B. (2006). Estimating the Local Cost of Protecting Koshi Tappu Wildlife Reserve, Nepal: A Contingent Valuation Approach. *Environment, Development and Sustainability*, 9(4):413.

Shyamsundar, P. and Kramer, R. A. (1996). Tropical Forest Protection: An Empirical Analysis of the Costs Borne by Local People. *Journal of Environmental Economics and Management*, 31(2):129–144.

Statistics Canada (2019). 2016 Census of Population, Catalogue no. 98-400-X2016097. Technical report.

Stern, D. I. (1997). Limits to Substitution and Irreversibility in Production and Consumption: A Neoclassical Interpretation of Ecological Economics. *Ecological Economics*, 21(3):197–215.

Sterner, T. and Persson, U. M. (2008). An Even Sterner Review: Introducing Relative Prices into the Discounting Debate. *Review of Environmental Economics and Policy*, 2(1):61–76.

Stevens, T. H., Echeverria, J., Glass, R. J., Hager, T., and More, T. A. (1991). Measuring the Existence Value of Wildlife: What Do CVM Estimates Really Show? *Land Economics*, 67(4):390–400.

Stone, R. (1954). Linear Expenditure Systems and Demand Analysis: An Application to the Pattern of British Demand. *The Economic Journal*, 64(255):511–527.

Strasnick, S. (1981). *Neo-Utilitarian Ethics and the Ordinal Representation Assumption*, pages 63–92. Springer Netherlands, Dordrecht.

Thompson, D. Y., Swallow, B. M., and Luckert, M. K. (2017). Costs of Lost Opportunities: Applying Non-Market Valuation Techniques to Potential REDD+ Participants in Cameroon. *Forests*, 8(3):69.

Treasury, H. M. (2018). The Green Book: Central Government Guidance on Appraisal and Evaluation. *London: HM Treasury.*

Van Parijs, P. and Vanderborght, Y. (2017). *Basic Income: A Radical Proposal, for a Free Society and a Sane Economy.* Harvard University Press.

Van Wee, B. (2012). How Suitable is CBA for the Ex-Ante Evaluation of Transport Projects and Policies? A Discussion from the Perspective of Ethics. *Transport Policy*, 19(1):1–7.

Veisten, K., Navrud, S., and Valen, J. S. Y. (2006). Lexicographic Preference in Biodiversity Valuation: Tests of Inconsistencies and Willingness to Pay. *Journal of Environmental Planning and Management*, 49(2):167–180.

World Bank (2018). Poverty and Shared Prosperity 2018: Piecing Together the Poverty Puzzle. Washington, DC: World Bank.

Appendix A Deriving $\boldsymbol{WTP_i}$ from appropriate *ex post* distributional weights

Let us first consider whether an *ex post* weight based on the marginal utility of income can properly account for the effect of subsistence needs. For an individual i with preferences (α_i, θ_i) and one non-market good $q_{i,1}$, the marginal utility of income V_i^s is equal to:

$$V_i^s = \frac{\partial u_i^s(.)}{\partial x_i} = \frac{\partial[\alpha_i(x_i - x_s)^{\theta_i} + (1-\alpha_i)q_{i,1}^{\theta_i}]^{\frac{1}{\theta_i}}}{\partial x_i}$$

$$= [\alpha_i(x_i - x_s)^{\theta_i} + (1-\alpha_i)q_{i,1}^{\theta_i}]^{\frac{1-\theta_i}{\theta_i}} \alpha_i(x_i - x_s)^{\theta_i - 1}$$

If we weight the WTP_i^s in the model with subsistence needs (Eq. (6)) by the marginal utility of income, we obtain:

$$WTP_{w_i}^s = V_i^s WTP_i^s = \frac{\partial u_i^s(.)}{\partial x_i}\frac{\partial u_i^s(.)/\partial q_{i,1}}{\partial u_i^s(.)/\partial x_i} = \frac{\partial u_i^s(.)}{\partial q_{i,1}} = [\alpha_i(x_i - x_s)^{\theta_i} + (1-\alpha_i)q^{\theta_i}]^{\frac{1-\theta_i}{\theta_i}}(1-\alpha_i)q^{\theta_i - 1}$$

The resulting $WTP_{w_i}^s$ still depends on the level of subsistence needs x_s: accounting for the marginal utility of income does not fully account for the effect of subsistence needs.

Theoretically, we can find a "social weight", denoted SW_i, and obtain the same WTP_i as that obtained with the subsistence-needs adjustment but after weighting by the marginal utility of income and a utilitarian SWF. This social weight would be equal to:

$$SW_i = \frac{[\alpha_i(x_i - x_s)^{\theta_i} + (1-\alpha_i)q_{i,1}^{\theta_i}]^{\frac{\theta_i - 1}{\theta_i}}}{\alpha_i x_i^{\theta_i - 1}}$$

The implied SWF is defined by the primitive of this social weight with respect to WTP_i^s. The $WTP_{w_i}^s$ weighted by the marginal utility of income and by SW_i would then be equal to:

$$WTP_{SW_i}^s = SW_i V_i^s WTP_i^s \equiv WTP_i$$

In practice, the SW_i is almost impossible to elicit without specific surveys asking for individual preferences on different combinations of income and non-market-good levels (Fleurbaey et al., 2013; Samson et al., 2018).

Appendix B Condition for ranking reversal

Ranking reversal occurs when the relative ranking of 2 projects (A and B) depends on the way they are evaluated (via observed WTP^s or subsistence-needs adjusted WTP). We use the notations previously introduced.

A] Consider that project A is ranked first based on observed WTP^s (condition A1) but ranked second based on adjusted WTP (condition A2), i.e.:
$(A1) : NWTP^s_{H,A} + MWTP^s_{L,A} > NWTP^s_{H,B} + MWTP^s_{L,B}$ and
$(A2) : NWTP_{H,B} + MWTP_{L,B} > NWTP_{H,A} + MWTP_{L,A}$

A-I] Assume that $\boldsymbol{\alpha_{H,A} < \alpha_{H,B}}$.

A-Ia] Assume that $\boldsymbol{\alpha_{L,A} \leq \alpha_{L,B}}$.

Ranking reversal is meaningless, as both income groups prefer project B.

A-Ib] Assume that $\boldsymbol{\alpha_{L,A} > \alpha_{L,B}}$.

When ranking is based on observed $\boldsymbol{WTP^s}$, condition (A1) leads to (from Eq. (9)):

$$N\frac{\alpha_{H,A}}{\alpha_0}\left(\frac{q}{x_H - x_s}\right)^{\theta-1} + M\frac{\alpha_{L,A}}{\alpha_0}\left(\frac{q}{x_L - x_s}\right)^{\theta-1} > N\frac{\alpha_{H,B}}{\alpha_0}\left(\frac{q}{x_H - x_s}\right)^{\theta-1} + M\frac{\alpha_{L,B}}{\alpha_0}\left(\frac{q}{x_L - x_s}\right)^{\theta-1}$$

$$\iff N\alpha_{H,A}\left(x_H - x_s\right)^{1-\theta} + M\alpha_{L,A}\left(x_L - x_s\right)^{1-\theta} > N\alpha_{H,B}\left(x_H - x_s\right)^{1-\theta} + M\alpha_{L,B}\left(x_L - x_s\right)^{1-\theta}$$

$$\iff M\left(x_L - x_s\right)^{1-\theta}\left(\alpha_{L,A} - \alpha_{L,B}\right) > N\left(x_H - x_s\right)^{1-\theta}\left(\alpha_{H,B} - \alpha_{H,A}\right)$$

Because $x_H > x_L > x_s$, we have:

$$\left(\frac{x_H - x_s}{x_L - x_s}\right)^{1-\theta} < \frac{M}{N}\frac{\alpha_{L,A} - \alpha_{L,B}}{\alpha_{H,B} - \alpha_{H,A}} \tag{13}$$

We know that $\alpha_{L,A} = 1 - \alpha_0 - \alpha_{L,B}$ and $\alpha_{H,B} = 1 - \alpha_0 - \alpha_{H,A}$, hence:

$$\left(\frac{x_H - x_s}{x_L - x_s}\right)^{1-\theta} < \frac{M}{N}\frac{1 - \alpha_0 - 2\alpha_{L,B}}{1 - \alpha_0 - 2\alpha_{H,A}}$$

Then, because $\alpha_{H,A} < \alpha_{H,B}$ and $\alpha_{L,A} > \alpha_{L,B}$, we have $1 - \alpha_0 - 2\alpha^H_A > 0$ and $1 - \alpha_0 - 2\alpha_{L,B} > 0$. Easy manipulations lead to:

$$\frac{1}{2}\left(1-\alpha_0-\frac{N}{M}\left(\frac{x_H-x_s}{x_L-x_s}\right)^{1-\theta}(1-\alpha_0-2\alpha_{H,A})\right)>\alpha_{L,B}$$

When ranking is based on adjusted *WTP*, and by the same reasoning, condition (A2) leads to (from Eq. (8)):

$$\frac{1}{2}\left(1-\alpha_0-\frac{N}{M}\left(\frac{x_H}{x_L}\right)^{1-\theta}(1-\alpha_0-2\alpha_{H,A})\right)<\alpha_{L,B}$$

Consequently, conditions (A1) and (A2) taken together implies that:

$$\frac{1}{2}\left(1-\alpha_0-\frac{N}{M}\left(\frac{x_H-x_s}{x_L-x_s}\right)^{1-\theta}(1-\alpha_0-2\alpha_{H,A})\right)>\alpha_{L,B}>\frac{1}{2}\left(1-\alpha_0-\frac{N}{M}\left(\frac{x_H}{x_L}\right)^{1-\theta}(1-\alpha_0-2\alpha_{H,A})\right)$$

hence the ranking reversal condition:

$$1-\alpha_0-\frac{N}{M}\left(\frac{x_H-x_s}{x_L-x_s}\right)^{1-\theta}(1-\alpha_0-2\alpha_{H,A})>2\alpha_{L,B}>1-\alpha_0-\frac{N}{M}\left(\frac{x_H}{x_L}\right)^{1-\theta}(1-\alpha_0-2\alpha_{H,A})$$

AII] Assume that $\boldsymbol{\alpha_{H,A}>\alpha_{H,B}}$.

AII-a] Assume that $\boldsymbol{\alpha_{L,A}\geq\alpha_{L,B}}$.

Ranking reversal is meaningless, as both income groups prefer project A.

A-IIb] Assume that $\boldsymbol{\alpha_{L,A}<\alpha_{L,B}}$

By the same reasoning as in Ib], condition (A1) leads to:

$$\frac{1}{2}\left(1-\alpha_0-\frac{N}{M}\left(\frac{x_H-x_s}{x_L-x_s}\right)^{1-\theta}(1-\alpha_0-2\alpha_{H,A})\right)<\alpha_{L,B}$$

and condition (A2) leads to:

$$\frac{1}{2}\left(1-\alpha_0-\frac{N}{M}\left(\frac{x_H}{x_L}\right)^{1-\theta}(1-\alpha_0-2\alpha_{H,A})\right)>\alpha_{L,B}$$

Consequently, we have:

$$\frac{1}{2}\left(1-\alpha_0-\frac{N}{M}\left(\frac{x_H-x_s}{x_L-x_s}\right)^{1-\theta}(1-\alpha_0-2\alpha_{H,A})\right)<\alpha_{L,B}<\frac{1}{2}\left(1-\alpha_0-\frac{N}{M}\left(\frac{x_H}{x_L}\right)^{1-\theta}(1-\alpha_0-2\alpha_{H,A})\right)$$

This condition cannot be met since $(1-\alpha_0-2\alpha_{H,A})<0$ and $\left(\frac{x_H-x_s}{x_L-x_s}\right)^{1-\theta}>\left(\frac{x_H}{x_L}\right)^{1-\theta}\forall x_H,x_L,x_s,\theta$ in their respective previously-defined domains of definition.

A-III] Assume that $\boldsymbol{\alpha_{H,A} = \alpha_{H,B}}$.

Ranking reversal is meaningless: Equation (13) cannot be met since $\left(\frac{x_H - x_s}{x_L - x_s}\right)^{1-\theta} > 0$.

B] Consider that project B is ranked first based on observed WTP^s (condition A3) but ranked second based on adjusted WTP (condition A4), i.e.:

$(A3) : NWTP^s_{H,A} + MWTP^s_{L,A} < NWTP^s_{H,B} + MWTP^s_{L,B}$ and

$(A4) : NWTP_{H,B} + MWTP_{L,B} < NWTP_{H,A} + MWTP_{L,A}$

We use the symmetry argument to obtain the same valid ranking reversal condition as in A].

B-I] Assume that $\boldsymbol{\alpha_{H,A} > \alpha_{H,B}}$.

B-Ia] Assume that $\boldsymbol{\alpha_{L,A} \geq \alpha_{L,B}}$.

Ranking reversal is meaningless, as both income groups prefer project A.

B-Ib] Assume that $\boldsymbol{\alpha_{L,A} < \alpha_{L,B}}$.

See A-Ib] for the proof of the ranking reversal condition.

B-II] Assume that $\boldsymbol{\alpha_{H,A} < \alpha_{H,B}}$.

B-IIa] Assume that $\boldsymbol{\alpha_{L,A} \leq \alpha_{L,B}}$.

Ranking reversal is meaningless, as both income groups prefer project B.

B-IIb] Assume that $\boldsymbol{\alpha_{L,A} > \alpha_{L,B}}$.

Impossible (see A-IIb] for proof).

B-III] Assume that $\boldsymbol{\alpha_{L,A} = \alpha_{H,B}}$.

Ranking reversal is meaningless (see A-III]).

Appendix C Pattern of preferences leading to a ranking reversal between two projects when $\theta = 0$ and $\theta = -0.5$

Figure C1. $\theta = 0$

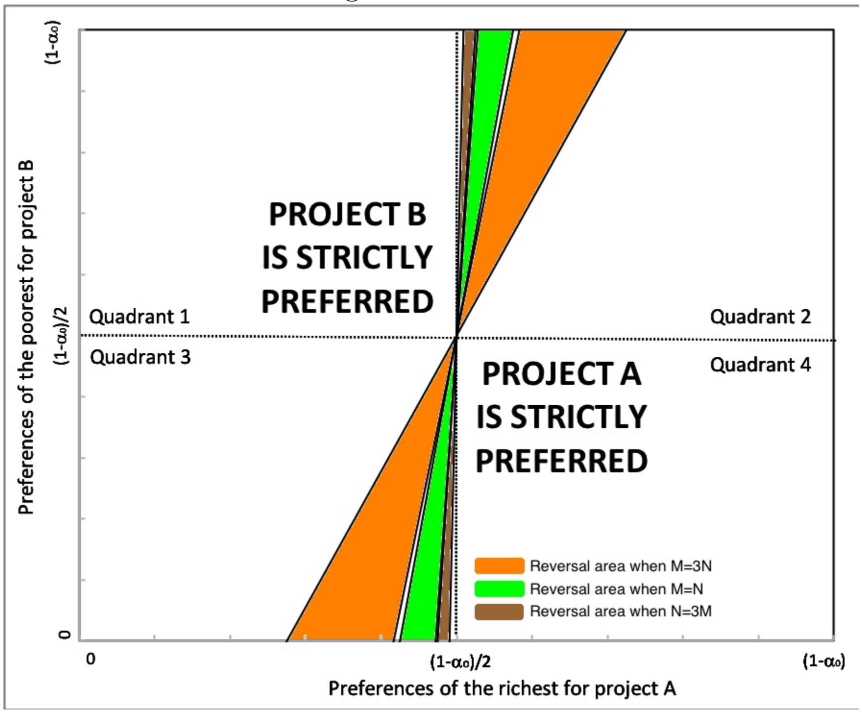


Figure C2. $\theta = -0.5$ (complementarity)