Del Campo, Stellio; Anthoff, David; Kornek, Ulrike

Working Paper

Inequality aversion for climate policy

Inequality aversion for climate policy

Stellio Del Campo[1], David Anthoff[*2], and Ulrike Kornek[1, 3, 4]

[1]Mercator Research Institute on Global Commons and Climate Change

[2]UC Berkeley

[3]Potsdam Institute for Climate Impact Research

[4]Christian-Albrechts-Universität Kiel

May 20, 2021

Abstract

A sizeable body of literature on climate economics utilizes the notion of inequality aversion. We review and synthesize published estimates of inequality aversion to guide this literature. We review both axiomatic and empirical studies, accordingly our findings draw on different lines of evidence. In the former case, a variety of ethical principles underlie the recommendations for positive inequality aversion. The latter studies use various methods to present estimates based on some form of "revealed ethics," for example by looking at existing progressive income tax-schedules or the level of foreign aid. Here we find strong support for the view that inequality aversion is positive (but potentially small) and very little support for any value larger than three. The vast majority of studies that look at domestic policies support values between one and two, whereas studies that look at foreign aid find lower values ranging from above zero to unity.

[*]Corresponding author.

Keywords: inequality aversion, marginal valuation of income, Atkinson index, climate change

JEL Classification: D63, I31, Q54

1 Introduction

The last few decades have seen the development of a sizeable body of theoretical and modeling literature exploring the effect of inequality aversion on estimates of the Social Cost of Carbon (SCC) and optimal climate policy (Azar and Sterner, 1996; Anthoff et al., 2009; Tol, 2010; Dennig et al., 2015; Adler et al., 2017; Anthoff and Emmerling, 2019; Budolfson and Dennig, 2020; Kornek et al., 2021). The insights from this literature have not been confined to academia but have been used in high-stakes climate policy applications. For example, both the original UK SCC estimate (Clarkson and Deyes, 2002) and the estimate from the German *Umweltbundesamt* (Astrid and Bünger, 2019) have incorporated inequality aversion in their approach by using equity-weighted SCC estimates. Any such equity-weighting approach must make a choice regarding the level of inequality aversion to be used in the analysis, and previous papers have shown that the choice of inequality aversion can be as important as the much-discussed choice of discount rate (Dennig et al., 2015). Somewhat surprisingly, the literature on inequality aversion in the climate context is thin when it comes to discussing appropriate values of inequality aversion. Theoretical literature largely skirts this question entirely, while modeling literature often uses ad-hoc choices or sensitivity analysis for their selection of inequality aversion levels.

Here we review various approaches proposed in the literature to pin down values for inequality aversion, systematically collecting empirical estimates of inequality aversion from the literature and drawing conclusions about the inequality-aversion values that are appropriate for use in climate economics. Our results are informative for future academic work on applications of inequality aversion in the climate literature, as well as for policy applications that have chosen to utilize inequality-aversion

principles in their analysis.

Inequality aversion as used in the literature we are concerned with is captured by a normative parameter in the social welfare function (Atkinson, 1970). There is another body of literature on inequality aversion in preferences (Fehr and Schmidt, 1999). This has no bearing on our topic. The parameter controls the degree to which a social planner is willing to trade higher total consumption for a more equal distribution of consumption. To some extent, it is similar to a risk-aversion parameter in an expected-utility framework capturing the trade-off between higher expected payoffs and the uncertainty of those payoffs. In fact, the mathematical structure of common inequality-aversion formulations is identical to the well-known constant relative risk-aversion utility formulation. The crucial difference between inequality aversion and risk aversion is that risk aversion reflects individual preferences that can in principle be measured, whereas inequality aversion encodes how consumption should be distributed between individuals, i.e. the underlying principle is normative.

In response to ethical questions, the classical philosophical-ethical approach is to identify general principles of what makes "good" behavior good and to develop arguments in their favor. There is a small body of theoretical literature in that tradition outlining what some plausible ethical axioms imply for admissible ranges of inequality aversion, and this literature forms one of the two lines of evidence that we review in this paper (Fleurbaey and Michel, 2001; Buchholz and Schumacher, 2010; Piacquadio, 2017). The second line of evidence uses empirical data to infer inequality-aversion values. Examples include studies attempting to infer the inequality-aversion parameters that would, for example, justify observed progressive income-tax schedules (e.g. Stern, 1977; Groom and Maddison Pr., 2019), or explain choices in income-distribution experiments (e.g. Amiel et al., 1999; Atkinson et al., 2009). We also provide new estimates of inequality aversion that explain observed levels of foreign aid, thus adding to the existing literature on this line of evidence (Evans, 2008; Tol, 2010). Such approaches can broadly be classified as

"revealed ethics," i.e. the implicit assumption underlying these approaches is that existing policies reflect what is "good" or what "should" be done. From a philosophical point of view this is an heroic assumption. It is, after all, entirely possible for all existing public policies that we can observe to be bad from an ethical point of view, and that by inferring inequality-aversion levels from observed policies, all we are doing is perpetuating bad policies. While this is certainly true, we nevertheless believe that reviewing existing policies for inequality aversion provides an important input for the discussion on inequality aversion in climate policy. There are two potential reasons for this position. First, existing policies in non-climate areas are not necessarily bad and thus may represent an important benchmark. Second, one might take the view that it is important to apply consistent inequality-aversion values across a range of policies. In the latter case, our review provides a helpful guide on how to design climate policy based on similar inequality-aversion principles to policies in other areas, for instance income taxation.

Inequality aversion in a social welfare function can control two different types of inequality: inequality in consumption between agents at different points in time (i.e. the prescriptive discounting debate) and inequality between agents at any given point in time. Following Anthoff and Emmerling (2019), we refer to inequality aversion in the former case as intertemporal inequality aversion and in the latter as intratemporal inequality aversion. In this review, we focus exclusively on intratemporal inequality aversion and review the literature for proposed estimates of its value. There is an enormous body of literature on the intertemporal aspect of this issue (e.g. Heal, 2009; Arrow et al., 2012). In this review, we leave this strand of the literature largely out of account. One might however argue that inequality between individuals at any given point in time and between individuals at different points in time should not be evaluated differently. If one espouses this viewpoint, then our review of intratemporal inequality aversion adds to the literature on intertemporal inequality aversion as well.

One complication in the climate-economics literature is that the most commonly

used utilitarian welfare function is parameterized with one parameter that controls not just intertemporal and intratemporal inequality aversion but also risk aversion (Atkinson et al., 2009). A welfare function of this kind forces one to use the same value for all three concepts, even if there are good reasons for using different values for them. Alternative welfare functions that disentangle these concepts do however exist. The work by Epstein and Zin (1989) has long since indicated a way of disentangling intertemporal substitution elasticity and risk aversion, while Anthoff and Emmerling (2019) develop a welfare function that disentangles inter- and intratemporal inequality aversion, and Berger and Emmerling (2020) have recently presented an approach that disentangles all three concepts. As our review specifically focuses on intratemporal inequality aversion, it will be best to employ one of the welfare functions that enable us to specify intratemporal inequality aversion independently from the other two concepts.

Our main results are as follows: The systematic review of the literature identifies twenty-four studies that provide inequality-aversion estimates based on the revealed-ethics approach and three papers based on the axiomatic approach. We find that all inequality aversion estimates are strictly positive, with a single exception in Pirttilä and Uusitalo (2010). None of the three axiomatic studies provide a clear upper bound on inequality aversion. For the revealed-ethics literature, we observe that estimates of inequality aversion are consistently above or below one, depending on which type of data was used in the experiment. Where the entire tax system or income distribution within a country is evaluated, values are usually above one, with most estimates between one and two. However, where the experiment evaluates a transaction in which a defined individual or group of individuals donates income to increase the income of a defined (group of) recipient(s), especially in the context of foreign aid, inequality aversion is usually below one. On the whole, we find little support for values of inequality aversion above three.

2 Framework

2.1 Social welfare function

We assume that society's preferences for equality can be represented by the following constant relative inequality-aversion social welfare function (Atkinson, 1970):

$$W(c_1,\ldots,c_N) = \begin{cases} \sum_{i=1}^{N} \frac{c_i^{1-\eta}}{1-\eta} & \text{if} \quad \eta \neq 1 \\ \sum_{i=1}^{N} \ln(c_i) & \text{if} \quad \eta = 1 \end{cases}, \tag{1}$$

where η is society's inequality aversion and c_i are individuals' consumption values. Optimal climate policy and SCC estimates based on a utilitarian welfare function or (equivalently) using equity weights are largely derived using (1) as default or important benchmark (Azar and Sterner, 1996; Anthoff et al., 2009; Dennig et al., 2015; Lessmann et al., 2015; Adler et al., 2017; Anthoff and Emmerling, 2019; Astrid and Bünger, 2019). Our purpose is to inform the academic community and policy-makers of the considerations involved in choosing a value for η.

Note that, in our setting, society neither evaluates how much agents consume over time nor in different, uncertain states of the world (there is no time index or uncertainty in the allocations c_i). We restrict our analysis to representing how averse society is to inequality at any given point in time.

The revealed-ethics literature almost exclusively measures income inequality aversion instead of consumption inequality aversion, i.e. these studies replace how much agents consume with how much they earn in (1) and estimate the η-parameter based on these social preferences. Income and consumption inequality aversion coincide if the saving rate is constant across income levels (Stern, 1977). See the on-line appendix A for more details and ways of correcting for estimates of η based on income if the savings rate varies with income.

2.2 Empirical strategy

For our review, we have drawn upon two academic literature databases: Web of Science and Scopus (see the on-line appendix B.1 for the exact terms of the query). The search query was designed to identify papers estimating the marginal social value of consumption, with alternative formulations encoded in the query based on a number of previous studies. The initial query came up with 830 papers. After manually screening titles and abstracts, a total of 147 full texts remained.

Ultimately, we found twenty-four publications estimating inequality aversion based on revealed ethics, i.e. using data derived from ethical choices. These twenty-four papers include studies cited in the literature but absent from the literature databases. We disregarded all studies estimating consumption or income elasticities based on consumer demand, savings and other dynamic decisions (these have to do with intertemporal consumption-smoothing motives), or based on risk aversion only.

From the twenty-four studies we extracted 435 estimates for the inequality-aversion parameter η. Many studies provide more than one estimate, based either on different samples (for example different times, countries or income brackets), alternative indicators for income, or different methods (see below). We included all estimates unless the authors explicitly stated that a specific estimate they had included was incorrect (due to data issues or for methodological reasons).

We found three studies that derive values for inequality aversion from axioms.

2.3 Revealed ethics: choice, methods, and data

The revealed ethics literature uses different empirical strategies to estimate the value of, or range for, η. We categorize these strategies in accordance with the following three dimensions.

In the first dimension, choices are either hypothetical or actual. Hypothetical choices are elicited from surveys where respondents evaluate hypothetical situations and their choices have no real-world consequences. Estimates based on actual

choices use real-world data from choices that have been made.

The second dimension is what we call "method." Empirical estimates of inequality aversion are mostly based on the approaches "leaky bucket," "inverse optimum," or "equal sacrifice." We describe these methods below.

The third dimension specifies the type of data used to make decisions, for example, income tax systems, income distributions, or foreign aid. The type of data is often bound up with the method. We detail the use of different data in our discussion of different methods below.

The supplementary material contains all estimates from the revealed ethics literature citing references and documenting choice, method, and data type.

The leaky-bucket method

Okun (1975) devised a "leaky bucket" experiment to assess inequality aversion. Suppose one can transfer one dollar from an individual with income \$5,000 to an individual with income \$1,000. The transfer is leaky so that part of the dollar is lost (e.g. administrative costs) and the second individual receives only a fraction of the original amount. What is the maximum tolerable leakage rate so that the transfer is still considered beneficial? The answer directly enables us to estimate income inequality aversion. The estimate depends on the income ratio and the leakage rate, please see the on-line appendix A.1 for the formula.

Different types of data have been used to conduct the leaky bucket experiment. The one outlined above is the most straightforward. It is what we have termed a "discrete transfer" case. The hypothetical choice experiment defines a transfer of funds from person A to person B without leakage. The respondents are asked whether they find the transfer acceptable. Questions continue with higher and higher leakage rates until the transfer is no longer accepted (Amiel et al., 1999; Pirttilä and Uusitalo, 2010; Cropper et al., 2016).

We have termed the second type of data "income distribution." Respondents are presented with distributions of income featuring different inequalities/means and

asked which "society" they would prefer. In choosing among societies, the participants face a trade-off: A society with lower inequality also has lower mean income. This is where the leaky bucket nature of the experiment comes in. Progressing to a more equal society involves a loss of money. Transfers are therefore implicitly leaky. From the choices made the inequality aversion parameter can be inferred (Johansson-Stenman et al., 2002; Carlsson et al., 2003; Carlsson et al., 2005; Atkinson et al., 2009; Hurley et al., 2020).

Note that the "income distribution" category may correspond to three different types of data. Hurley et al. (2020), for example, explicitly refer to the national distribution of income in Canada. Others, like Johansson-Stenman et al. (2002) and Carlsson et al. (2005), refer to a hypothetical society in which an imaginary grandchild lives. Finally, Atkinson et al. (2009) consider the distribution of income on the global scale. We regard these different types of data as belonging to the same category because fundamentally they are all examples of the same situation (implicit leakiness).

Income-distribution data often mix ethical inequality aversion with risk aversion (Kroll and Davidovitz, 2003). The two motives are mixed if respondents are part of the society they choose from, so that they may wish to hedge against their private income uncertainty through the choice of a society with less inequality. Carlsson et al. (2005), Atkinson et al. (2009), and Hurley et al. (2020) control for risk aversion to eliminate this motive.

Tol (2010) uses real-world development aid data. Here, actual transfers are evaluated in terms of a range of leakage rates to infer inequality aversion between countries based on their per-capita income differences.

To obtain more evidence on inequality aversion between countries, the present study provides new estimates that use reported leakage in foreign-aid projects. We review both the international leakage rates of foreign-aid projects referred to in the scientific literature and reports published by international institutions (see Table 1 below). Note that our new estimates are based on inequality in per-capita consump-

tion and not income.

The inverse optimum method

We classify a second group of papers as using an "inverse optimum" method. The foundation for this approach is the optimal income taxation literature. One classical result in that literature is that for higher inequality aversion values in the social welfare function one would design an optimal tax system that distorts the labor-leisure trade-off to a larger extent. Essentially, a planner is willing to accept a higher efficiency loss from an income-tax model in order to achieve a distributional objective when inequality aversion is higher. The idea in the studies that use the "inverse optimum" approach is to reverse this procedure: What inequality aversion fits the actual data on income taxation (Stern, 1977)? The trade-off between consumption and leisure brings this method very close to the leaky bucket experiment discussed above. Higher income tax reduces inequality but also distorts work incentives and thus leads to welfare loss.

Social inequality aversion can also be inferred from "indirect taxation" data. Christiansen and Jansen (1978) study the social preferences implicit in Norwegian consumption-tax data, i.e. the degree of inequality aversion that makes the tax system socially optimal.

The two articles in this category, Stern (1977) and Christiansen and Jansen (1978), are the only previous studies in the revealed-ethics category that estimate consumption inequality aversion rather than income inequality aversion. As the social welfare function features not only consumption but also other variables, these two studies diverge from the strict use of (1). However, the use of specific functional forms enables both studies to isolate consumption inequality aversion.

The equal sacrifice method

A venerable principle ensuring fairness in taxation is equal sacrifice on the part of taxpayers (Stern, 1977; Young, 1988). The sacrifice made by taxpayers is mea-

sured with a utility function in their income (Young, 1990). The utility function here represents a social norm and has the constant relative inequality aversion form. The equal sacrifice method assumes that an actual tax scheme ensures that every taxpayer bears the same sacrifice. In this method, the derived estimate of inequality aversion equalizes the sacrifice between individuals for a given tax data. (See the on-line appendix A.2 for the formula.)

This equal sacrifice principle has been used on different types of data, most frequently on actual choices via "income taxation" (Piggott, 1982; Sezer, 2006; Groom and Maddison Pr., 2019), but also on hypothetical income taxation (Evans et al., 2014). The tax may however be different from income taxation, where the literature used "fines" or contributions to "foreign aid" to estimate inequality aversion (Evans, 2008).

Other method

Moreh (1981) uses none of these methods. This study makes a different assumption about society, i.e. that there is a constant decline in income inequality as measured by the Atkinson index. Since the Atkinson index is based on our social welfare function (1), fitting actual income data to a constant decline in inequality provides an estimate for inequality aversion. Moreh (1981) is the only study that uses this approach.

2.4 Normative principles

Axiomatic literature can provide limits to the value of η. In this approach, the authors postulate that an allocation selected by the social welfare function will fulfil a number of normative principles. They include proportional transfers (Fleurbaey and Michel, 2001), equal-preference transfer (Piacquadio, 2017), and solidarity (Buchholz and Schumacher, 2010). Limits to inequality aversion can be directly inferred.

2.5 Comparing estimates from revealed ethics and normative principles

Estimates of inequality aversion based on the different revealed-ethics methods – leaky bucket, inverse optimum, equal sacrifice methods, and constant decline in inequality – are comparable to some degree among each other and with estimates based on the axiomatic approach. All approaches measure the curvature of the social welfare function in (1). Knowing the preferences of society, climate policy and SCC estimates based on (1) move society closer to a first-best world in which inequality and climate policy are addressed simultaneously.

The leaky bucket experiment measures the curvature of the social welfare function by ordinal comparisons of allocations. It assumes that revealed preferences can be represented by the social welfare function (1). The inverse-optimum method also assumes that social preferences can be represented by (1) and sets out to find the curvature of the social welfare function that makes the observed allocation optimal.

The equal-sacrifice method follows from a set of principles concerning distributive justice (Young, 1988). These principles imply that individual utility is necessarily represented by the iso-elastic form in Eq. (1) via income and is a representation of utility for the normative analysis of taxation (Young, 1990). Being a normative representation of utility, estimated inequality aversion may also serve as a basis for evaluating issues outside income taxation, as suggested by Cowell and Gardiner (2000), Evans and Sezer (2005), Groom and Maddison Pr. (2019), and others.

Moreh (1981) and the axiomatic literature (Fleurbaey and Michel, 2001; Bucholz and Schumacher, 2010; Piacquadio, 2017) use different assumptions about how governments influence inequality. These include constant decline in the Atkinson index over time, the proportional transfer principle, and others. Assuming that preferences on inequality can be represented by (1), they can estimate the curvature of the social welfare function consistent with their assumptions about governmental decisions.

Some reservations need to be noted. First, policy evaluations that use estimates

of inequality aversion based on the equal-sacrifice principle can be criticized because the equal-sacrifice assumption is not consistent with the Pareto principle (Berg and Piacquadio, 2020). Second, the method differs from the leaky bucket experiment in its assumptions about social preferences since the equal-sacrifice method follows from additional axioms about redistributive justice.

3 Results and discussion

3.1 Revealed ethics

Estimates of inequality aversion from the revealed-ethics literature

Estimates of inequality aversion from the revealed-ethics literature are plotted in Fig. 1. The estimates are expressed in terms of the dimensions choice, method, and data. The y-axis represents the type of data used, while the x-axis represents the value of the inequality-aversion parameter, ranging from zero to four (an arrow represents an undefined bound). We divide estimates according to actual (left) and hypothetical choices (right). Each color stands for a different method.

From Fig. 1 we first observe that, for a given combination of method and data type, estimates tend to cluster around certain defined values or ranges. Here is no observable difference between hypothetical and actual choices. The methods used in the literature appear to be quite consistent in their findings.

Estimates in Fig. 1, however, divide between values above or below $\eta \approx 1$ depending on the type of data. Estimates based on income distribution, income taxation, and indirect taxation have a value around one or higher for η. Estimates deriving from the equal-sacrifice method lie mainly in the range of one to two.

For discrete transfers, fines, and foreign aid, we observe values of one or lower for η. Decision-makers and survey respondents seem not to favor high transfers if the source of payment is explicitly identified as an individual or country. This finding has important implications for climate policy. The global public-good nature of greenhouse gas-emission reductions means that inequality between countries is

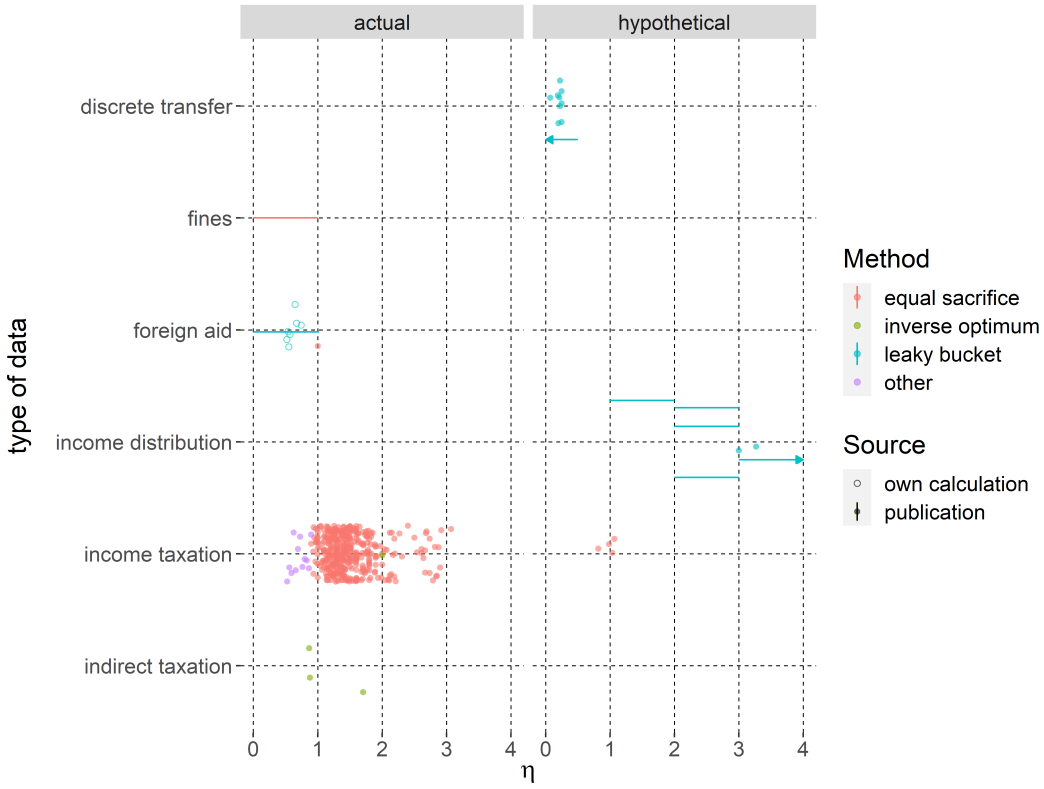

Figure 1: Inequality-aversion estimates in terms of choice, method, and data.
Note: Data available in the supplementary material.

a main driver for SCC estimates (Anthoff et al., 2009; Adler et al., 2017; Kornek et al., 2021) and burden-sharing in the international mitigation effort (Baer et al., 2009; Kornek et al., 2017). If the global community interprets climate policy in the US as a transfer to developing countries and uses this as a basis for its inequality-aversion choice in Fig. 1, somewhat lower inequality aversion would be chosen over and against an estimate derived from a predominantly national context. Anthoff and Emmerling (2019) show that lower values of intratemporal inequality aversion translate to a lower SCC estimate for the US compared to higher inequality aversion, and hence less ambitious US climate policy in a cost-benefit setting.

However, evidence of inequality aversion from foreign-aid decisions is scarce in Fig. 1. We have thus added our own estimates for inequality aversion based on leaky foreign aid to the figure (circles). We discuss these new values in more detail in subsection *Leakiness of foreign aid*. In Fig. 1, the additional data points confirm that inequality aversion is below one when it is estimated on the basis of foreign-aid

data.

Value $\eta = 1$ marks an interesting threshold in its implications for distributional policies. A value of $\eta = 1$ corresponds to a one-to-one ratio between levels and variations of incomes. Transposed to the leaky-bucket method, a value of $\eta = 1$ means that only a share r of the transfer may arrive if the income inequality ratio between the two individuals is r. Transposed to the equal-sacrifice method, individuals pay taxes proportional to their income (the tax is neutral). With $\eta > 1$, society favors more progressive redistribution, while regressive policies are socially preferable when $\eta < 1$.

Why do we observe such a division? One apparent difference between data types that produce high values of inequality aversion – income distribution, income taxation, indirect taxation – and data types that make for low values – discrete transfer, foreign aid – is the following: For the former, inequality is evaluated at the national level. The entire tax system or the entire income distribution within a country is evaluated by the decision-makers. Their choice does not create a single loser, rather all individuals receive – higher or lower – income or consumption without their identity being known. In this setting, people seem to be quite averse to inequality within countries, favoring progressive policies. For the latter types of data, donors directly lose from the decision. For discrete transfer, the donors are explicitly singled out. For foreign aid, the donor countries are known, bringing this type of data very close to the discrete-transfer case. It thus appears that if losses are direct, decision-makers will favor policies that lead to a less-than-proportional change in income. In addition, the foreign-aid data evaluates global inequality, whereas data with high inequality aversion describes inequality within countries. People may quite simply care more about their closer neighbors than unknown foreigners. An exception is Atkinson et al. (2009), who use an international income distribution and find a range of two to three. Here, the international aspect is outweighed by the fact of not explicitly knowing the donor-recipient constellation. We discuss the implications of these findings in more detail below.

Alongside the type of data, we have analyzed other possible drivers behind the different η estimates. We were unable to identify robust dependency of η on time, national income, and national inequality. Nor could we find any systematic bias according to authors (see the on-line appendix B.2). The two plots in the first row of Fig. 6 show estimates against the gross domestic product (GDP) per capita in constant dollars and in purchasing power parity (PPP) based on the national identity of the study sample. The second row shows estimates plotted against the Gini-index of the country and against time. In the first row, inequality aversion increases slightly with GDP in PPP: richer countries tend to be more inequality-averse. In the second row, inequality aversion follows a bell-curve relation with the Gini-index. Broadly speaking, inequality aversion is independent of the level of inequality, except when the level of inequality is very high, where a negative correlation appears. Finally, there is a slight downward-sloping trend for estimates over time. Despite the 1970s energy crisis and the increase in worldwide inequalities, inequality aversion dropped from around two in the 1970s to around one point five in the 2000s. The limitations on data and countries (most of them are developed countries) do not enable us to draw any general conclusions. The four plots however also show that estimates do not vary much with the indicators. The variation of estimates for given values of income, inequality, and time is much larger than the trends for indicators. Note that not all estimates are plotted in Fig. 2 due to data limitations.

So which inequality aversion should be chosen for climate policy analysis based on revealed ethics? Figure 1 helps in understanding that inequality aversion can be context-dependent and identifying the reasonable values that can be used in designing climate policies. Most estimates are in the range of $\eta = 1 \ldots 2$. For a rich country, a value nearer to two implies losing up to one hundred dollars in having a poor country (half GDP) earn twenty-five dollars instead of fifty dollars. Let us assume that an investment of one hundred dollars in the first country would reduce its emissions so damage to the tune of forty dollars is avoided in the second country. An aversion of two would be a recommendation to make the investment, while

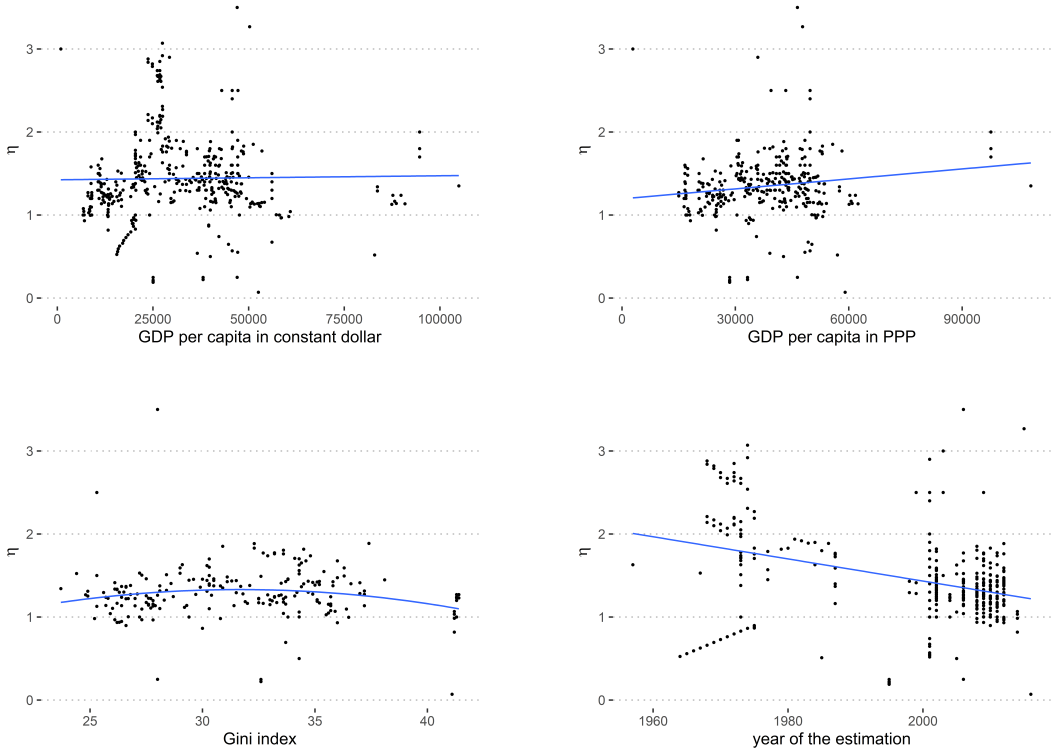

Figure 2: Inequality aversion estimates against GDP, inequality, and time.
Note: Data is available in the supplementary material.

an aversion of one would not. Since climate change inflicts damages on all countries and requires all countries to incur mitigation costs, the value of η is of crucial importance in determining urgency of action and allocation of efforts.

Another policy implication is that local impacts of climate change are more important due to the fact that foreign aid seems not to be a choice favored by citizens. Reducing inequality at home would receive greater weight than reducing global inequality. This is in line with the "home preference" feature that has been observed in connection with climate-related transfers (Buntaine and Prather, 2018). The public-good dimension of climate change becomes an important factor here. Although rising temperatures have similarly adverse impacts all across the globe, people may be less willing to pay to avoid impacts on people who are further away from them, be it spatially or geographically. This indicates a drawback in basing climate policies on revealed ethics because, although climate change is a global public bad that has similar effects everywhere, people may still be partial. Accordingly, in the next

Source	Percent lost	Sector	Recipient country	Donor country	η
Das et al. (2004)	89	education	Zambia	African Development Bank	
	94	education	Zambia	Denmark	0.67
	89	education	Zambia	Ireland	0.57
	94	education	Zambia	Japan	0.74
	89	education	Zambia	Netherlands	0.55
	89	education	Zambia	Norway	0.52
	96	education	Zambia	other (churches, NGOs)	
	89	education	Zambia	United Kingdom	0.54
	91	education	Zambia	UNICEF	
	94	education	Zambia	United States	0.65
	89	education	Zambia	World Bank	
Andersen et al. (2020)	08	aid	Afghanistan, Armenia, Burkina Faso, Burundi, Eritrea, Ethiopia, Ghana, Guinea-Bissau, Guyana, Kyrgyz Republic, Madagascar, Malawi, Mali, Mauritania, Mozambique, Niger, Rwanda, Sao Tome and Principe, Sierra Leone, Tanzania, Uganda, Zambia	World Bank	
	15	aid	Burundi, Eritrea, Guinea-Bissau, Malawi, Mozambique, Sierra Leone, Uganda	World Bank	
Asiimwe et al. (1997)	78	drugs	Uganda	central government & external donors	
McPake et al. (1999)	76	drugs	Uganda	central government & external donors	
Average	79				

Table 1: Leakage of international development aid and derived inequality-aversion estimates. Leakage is reported as percentage lost during the transfer.

section we present estimates of inequality aversion based on axioms able to avoid this kind of partiality.

Leakiness of foreign aid

The global public-bad nature of climate change makes inequality and inequality aversion between countries a central concern for climate-policy design (Anthoff et al., 2009; Anthoff and Emmerling, 2019). Figure 1 shows that there are only very few estimates of η derived from foreign aid that directly inform inequality aversion between countries. Accordingly, we list here more estimates made on this basis.

Tol (2010) estimates inequality aversion between countries from the leakiness of development aid. However, instead of providing one single estimate, the study only tests a range of leakage rates (from zero to ninety-five percent), stating that actual leakiness cannot be observed. To make Tol's estimates more precise, we review the international leakage rates referred to both in the literature and in reports published by international institutions. Table 1 shows that reported leakage has been quite

high: on average, the recipient country received about twenty percent of the initial amount. If we take this average and apply it to the data in Tol (2010), the range of this study narrows down to $\eta = 0.385 \ldots 0.554$ for the years 2005 to 1965.

Next, we calculate η directly from the data based on the leaky-bucket method. We use the per-capita consumption levels of donor and recipient countries when single donors were listed for the projects. (Data is available in the supplementary material.) Our estimates are slightly higher in comparison to Tol (2010). When leakage is above ninety percent, η is about zero point seven. A crucial difference between our estimates and those of Tol is that we evaluate foreign aid as a discrete transfer between the single donor and recipient countries in Table 1, while Tol uses a social welfare function aggregating all donor and recipient countries.

Overall, our additional estimates confirm that inequality aversion based on actual foreign aid is consistently below one.

3.2 Axiomatic literature

The axiomatic literature can be helpful in inferring the degree to which inequality aversion should be based on equity principles. Below, we set out the evidence on ranges for η found in the peer-reviewed literature. Not all contributions report levels directly, so that, where appropriate, we apply the results of these contributions to our social welfare function Eq. (1). The estimates are summarized in Table 2.

Fleurbaey and Michel (2001) analyze the principle of proportional transfers. The principle states that subsequent transfer increases social welfare. The amount of a resource like consumption owned by a rich agent is reduced by a certain percentage, while the amount of the resource owned by a poor agent increases by the same percentage. Fleurbaey and Michel (2001) find that the social welfare function needs to exhibit an inequality aversion of more than two to fulfill the proportional-transfer principle. In a slightly weaker form of the principle, η should be weakly larger than unity. As a large amount of the resource is lost during transfer, levels of η are quite high.

Piacquadio (2017) has introduced the *equal-preference transfer*, a generalization of the classic Pigou-Dalton principle. A transfer weakly enhances social welfare if (i) it does not reverse the order of welfares and (ii) reduces the distance between two indifference curves. A social criterion satisfying this principle has to be concave, i.e. exhibits inequality aversion so that η is positive.

Buchholz and Schumacher (2010) consider the choice of the social welfare function based on equity principles in the context of an intergenerational transfer. We reinterpret their results in our intra-generational context via the leaky-bucket thought experiment between two countries, i.e. a donor country making a leaky transfer to a recipient country. In Buchholz and Schumacher (2010), two generations are aggregated with the same functional form as in (1), and for each dollar of consumption forfeited by the current generation, the future generation consumes a value of more than one dollar. In our reinterpretation of this model, a transfer from the donor country (the future generation) to the recipient country (the current generation) is subject to a positive leakage rate. The requirement implicit in the first equity principle, solidarity, is that when the leakage rate of the transfer decreases, both countries should be better off in the final allocation chosen by society. Then, η should be above unity. The next principles are based on absence of envy between the two countries, i.e. at the chosen allocation, no country should want to exchange positions with the other country. In the narrower sense of the no-envy criterion, both countries consume the same, and η should be infinite. However, Buchholz and Schumacher (2010) argue that because the two countries differ in their economic circumstances (in our context because one country is able to make a leaky transfer to the other country), they should not be treated in the same way. In the case of no-envy in an absolute sense as a criterion, η should be unity. The criterion requires the ratio of absolute consumption between recipient and donor country to be equal to the share of transfer received (governed by the leakage rate). Lastly, Buchholz and Schumacher (2010) discuss the principle of no-envy in a relative sense. Here, agents do not compare absolute consumption but their relative position in society.

The ratio of absolute consumption between recipient and donor country is equal to the share of transfer received times the inverse ratio of consumption between recipient and donor country. In this case, η should be two.

Summarizing our search for guidance from the axiomatic literature on the level of η, we find no reason to limit the range of η. Rather, any positive value seems possible (Table 2). However, most equity principles point to η weakly larger than unity.

Source	η range	Principle
Fleurbaey and Michel (2001)	> 2	Proportional transfers
	≥ 1	Proportional transfers, ex-post
Piacquadio (2017)	> 0	Equal-preference transfer
Buchholz and Schumacher (2010)	> 1	Solidarity
	$= \infty$	Equality of consumption
	$= 1$	No-envy in absolute sense
	$= 2$	No-envy in relative sense

Table 2: η ranges from the axiomatic literature

4 Use of inequality aversion in previous studies

The climate-economics literature has applied various values for intratemporal inequality aversion to compute optimal climate policy and SCC estimates from integrated assessment models. Azar and Sterner (1996) analyze a continuous range between zero and three. Anthoff et al. (2009) frame their scenarios along the values: zero point five, one, and two. The same values have been used in the PAGE (Policy Analysis of the Greenhouse Effect) model developed by Hope (2011) and colleagues. Values of zero, one, and two have been used in the RICE (Regional Integrated Climate-Economy) model (Nordhaus, 2011). In the NICE (Nested Inequalities Climate-Economy) model, Dennig et al. (2015) use η equals two, while Kornek et al. (2021) use values of zero point five, one, one point five, and two. Anthoff and Emmerling (2019) assume a central value of zero point seven and apply a

continuous range between zero and one point five. All these values fall within the range identified in our systematic review.

Economic analysis of climate policy drawing upon inequality aversion has been used in a few real-world policy contexts. The first widespread use of the SCC in policy analysis was in the United Kingdom (Clarkson and Deyes, 2002), and those estimates used equity weighting with an inequality-aversion parameter value of one. The Stern Review (Stern, 2007) had a fairly extensive discussion of equity principles but did not actually use intratemporal inequality aversion for its main headline results. The *Umweltbundesamt* in Germany officially adopted an equity-weighted SCC that also uses an inequality aversion value of one (Astrid and Bünger, 2019). When the US adopted its official SCC estimate in 2010, it did not use equity weighting, and the most recent revision of the SCC under the Trump administration actually changed the official figure to a domestic SCC, i.e. one where impacts outside the US receive no weight at all. It should be revised under the Biden administration (Wagner et al., 2021).

It is also informative to compare our results for *intra*temporal inequality aversion with values that have been argued for in the *inter*temporal inequality-aversion context. Here the value of η is a main driver of the consumption discount rate for cost-benefit analysis (e.g. Heal, 2009; Arrow et al., 2012). For example, in his review, Stern (2007, p. 628) uses an intertemporal inequality-aversion value of one. In reply, Nordhaus (2007) argues that one should determine η and the pure rate of time preference in such a way that the effective discount rate in a model matches observed real-interest and savings rates. This prompts him to choose a value of two for η. He later reduces the value to one point forty-five in updates of his DICE (Dynamic Integrated Climate-Economy) model (Nordhaus, 2014, 2018). Weitzman (2007) suggests a value of two, whereas according to Dasgupta (2008), values between one point five and three are more reasonable. In its last assessment report, the IPCC proposes a consensus value between one and three (Kolstad et al., 2014). Again, all these values fall within the range of our systematic review.

5 Conclusion

Our review of inequality-aversion values does not reveal a single "best" value that we recommend for climate-economics applications. Nevertheless, there are some important conclusions to be drawn from it.

First, an inequality-aversion value of one is well within the range of values that our literature review suggests. A unitary inequality-aversion parameter is probably the most commonly used value in the climate-economics literature to date. Despite this fact, there has rarely been much justification for this particular value. Our review lends some minimal support to this choice, i.e. it demonstrates that it is not outside a plausible range.

Second, existing progressive income-taxation schedules in developed countries generally imply inequality-aversion values that are higher than one, somewhere in the range one to two. Inequality-aversion values in that range have also been used in the climate-economics literature (Dennig et al., 2015; Anthoff and Emmerling, 2019), and our review suggests that one can justify such a choice by arguing that climate policy should be based on a similar inequality aversion to what we observe in some domestic income-taxation schedules, or to income distributions favored by survey respondents.

Third, policy contexts that cover foreign aid generally exhibit inequality-aversion values smaller than one. If one considers climate policy primarily as an international problem and aims to make climate policy consistent with other international policies changing world inequality through foreign aid, one can use this line of evidence to argue for inequality-aversion values in this range. This is what Anthoff and Emmerling (2019) do, for example, in connection with their central estimate.

The discrepancy between the evidence from income-taxation studies and foreign-aid studies highlights the tension existing between a pragmatic position and a principled ethical stance. On the one hand it seems unlikely that countries would be willing to use a much higher inequality-aversion value for climate policy than for other international policies, and this could be used as an argument for one of the

lower inequality-aversion values. On the other, it seems highly dubious from an ethical point of view to support a different inequality-aversion value for domestic policies like income taxation and for international policies like foreign aid or climate policy. Such a position implicitly contradicts moral universalism, the core ethical principle that all human individuals should be treated equally.

Finally, our review suggests that intratemporal inequality-aversion values larger than three are not well supported by the existing literature. At the other end of the spectrum, we find that the lowest values are positive but very small, just above zero.

Normative principles encountered in the axiomatic literature do not point toward a precise value for inequality aversion, but they do provide support for ranges of values. Like empirical evidence, they strongly support strictly positive inequality-aversion values. Some axiomatic approaches imply values that are larger than two. These values are not outside the range that we see in empirical evidence, but they are certainly at the higher end of the figures from the revealed-ethics approach.

Our review reveals several important research needs for the future. The revealed-ethics literature focuses almost exclusively on developed countries. More evidence is needed on how inequality-averse societies in developing countries are. Related to this, more evidence is required on how averse global society is toward inequality between individuals in different countries, a parameter of the greatest importance in the context of climate-change policy. Little guidance is forthcoming from the axiomatic literature in choosing an inequality-aversion value. More discussion and analysis would be helpful, there is, for example, no upper bound on inequality aversion based on ethical principles. Lastly, our review has identified that different empirical strategies tend to give systematically higher or lower estimates of inequality aversion, e.g. hypothetical leaky-bucket experiments via direct transfers tend to give low estimates, while estimates are high when respondents choose income distributions. More research analyzing the reasons for these discrepancies would be helpful as a source of information for researchers and policy-makers.

Supplementary Material

The supplementary material to this article contains all data. An on-line appendix is available.

Acknowledgment

Stellio Del Campo gratefully acknowledges funding from the CHIPS project. CHIPS is part of AXIS, an ERA-NET initiated by JPI Climate, and funded by FORMAS (SE), DLR/BMBF (DE, Grant No. 01LS1904A-B), AEI (ES) and ANR (FR) with co-funding by the European Union (Grant No. 776608).

References

Adler, Matthew, David Anthoff, Valentina Bosetti, Greg Garner, Klaus Keller, and Nicolas Treich (2017). "Priority for the worse-off and the social cost of carbon." *Nature Climate Change* 7, pp. 443–449.

Amiel, Yoram, John Creedy, and Stan Hurn (1999). "Measuring Attitudes Towards Inequality." *The Scandinavian Journal of Economics* 101.1, pp. 83–96.

Andersen, Jørgen Juel, Niels Johannesen, and Bob Rijkers (2020). *Elite Capture of Foreign Aid: Evidence from Offshore Bank Accounts*. The World Bank.

Anthoff, David and Johannes Emmerling (2019). "Inequality and the Social Cost of Carbon." *Journal of the Association of Environmental and Resource Economists* 6.2, pp. 243–273.

Anthoff, David, Cameron Hepburn, and Richard S. J. Tol (2009). "Equity weighting and the marginal damage costs of climate change." *Ecological Economics* 68.3, pp. 836–849.

Arrow, Kenneth J., Maureen L. Cropper, Christian Gollier, Ben Groom, Geoffrey M. Heal, Richard G. Newell, William D. Nordhaus, Robert S. Pindyck, William A. Pizer, Paul R. Portney, Thomas Sterner, Richard S. J. Tol, and Martin L. Weitzman (2012). "How Should Benefits and Costs Be Discounted in an Intergenerational Context? The Views of an Expert Panel." *Resources for the Future, Discussion Paper No. 12-53*.

Asiimwe, D., F. Mwesigye, B. McPake, and P. Striefland (1997). *Informal Markets and Formal Health Financing Policy in Uganda*. Tech. rep.

Astrid, Matthey and Björn Bünger (2019). *Methodological Convention 3.0 for the Assessment of Environmental Costs*. Tech. rep. German Environmental Agency.

Atkinson, Anthony B. (1970). "On the Measurement of Inequality." *Journal of Economic Theory* 2.3, pp. 244–263.

Atkinson, Gilles, Simon Dietz, Jennifer Helgeson, Cameron Hepburn, and Häkon Sælen (2009). "Siblings, Not Triplets: Social Ppreferences for Risk, Inequality and Time in Discounting Climate Change." *Economics: The Open-Access, Open-Assessment E-Journal* 3.26.

Azar, Christian and Thomas Sterner (1996). "Discounting and distributional considerations in the context of global warming." *Ecological Economics* 19.2, pp. 169–184.

Baer, Paul, Tom Athanasiou, Sivan Kartha, and Eric Kemp-Benedict (2009). "Greenhouse development rights: A proposal for a fair global climate treaty." *Ethics, Place & Environment* 12.3, pp. 267–281.

Berg, Kristoffer and Paolo G. Piacquadio (2020). "The Equal-Sacrifice Social Welfare Function with an Application to Optimal Income Taxation." *CESifo Working Paper* 8505.

Berger, Loïc and Johannes Emmerling (2020). "Welfare as Equity Equivalents." *Journal of Economic Surveys* 34.4, pp. 727–752.

Buchholz, Wolfgang and Jan Schumacher (2010). "Discounting and welfare analysis over time: Choosing the η." *European Journal of Political Economy* 26.3, pp. 372–385.

Budolfson, Mark and Francis Dennig (2020). "Optimal global climate policy and regional carbon prices." In *Handbook on the Economics of Climate Change*. Edward Elgar Publishing.

Buntaine, Mark T. and Lauren Prather (2018). "Preferences for Domestic Action Over International Transfers in Global Climate Policy." *Journal of Experimental Political Science* 5.2, pp. 73–87.

Carlsson, F., G. Gupta, and O. Johansson-Stenman (2003). "Choosing from behind a veil of ignorance in India." *Applied Economics Letters* 10.13, pp. 825–827.

Carlsson, Fredrik, Dinky Daruvala, and Olof Johansson-Stenman (2005). "Are People Inequality-Averse, or Just Risk-Averse?" *Economica* 72.287, pp. 375–396.

Christiansen, Vidar and Eilev S. Jansen (1978). "Implicit social preferences in the Norwegian system of indirect taxation." *Journal of Public Economics* 10.2, pp. 217–245.

Clarkson, Richard and Kathryn Deyes (2002). "Estimating the Social Cost of Carbon Emissions." *Government Economic Service Working Paper* 140.

Cowell, Frank A. and Karen Gardiner (2000). *Welfare weights*. Office of Fair Trading London.

Cropper, Maureen, Alan Krupnick, and William Raich (2016). *Preferences for Equality in Environmental Outcomes*. Working Paper 22644. National Bureau of Economic Research.

Das, Jishnu, Stefan Dercon, James Habyarimana, and Pramila Krishnan (2004). *Public and private funding of basic education in Zambia: implications of budgetary allocations for service delivery*. Tech. rep. Africa Region Human Development working paper series; no. 62; Africa education country status report Washington, D.C.: World Bank Group.

Dasgupta, Partha (2008). "Discounting climate change." *Journal of Risk and Uncertainty* 37.2, pp. 141–169.

Dennig, Francis, Mark B. Budolfson, Marc Fleurbaey, Asher Siebert, and Robert H. Socolow (2015). "Inequality, climate impacts on the future poor, and carbon prices." *Proceedings of the National Academy of Sciences* 112.52, pp. 15827–15832.

Epstein, Larry G. and Stanley E. Zin (1989). "Substitution, Risk Aversion, and the Temporal Behavior of Consumption and Asset Returns: A Theoretical Framework." *Econometrica* 57.4, pp. 937–969.

Evans, David (2008). "The marginal social valuation of income for the UK." *Journal of Economic Studies* 35.1, pp. 26–43.

Evans, David J. and Haluk Sezer (2005). "Social discount rates for member countries of the European Union." *Journal of Economic Studies* 32.1, pp. 47–59.

Evans, David John, Erhun Kula, and Yoko Nagase (2014). "The social valuation of income: a survey approach." *Journal of Economic Studies* 41.6, pp. 808–820.

Fehr, Ernst and Klaus M. Schmidt (1999). "A Theory of Fairness, Competition, and Cooperation." *The Quarterly Journal of Economics* 114.3, pp. 817–868.

Fleurbaey, Marc and Philippe Michel (2001). "Transfer principles and inequality aversion, with an application to optimal growth." *Mathematical Social Sciences* 42.1, pp. 1–11.

Groom, Ben and David Maddison Pr. (2019). "New Estimates of the Elasticity of Marginal Utility for the UK." *Environmental and Resource Economics* 72.4, pp. 1155–1182.

Heal, Geoffrey (2009). "Climate Economics: A Meta-Review and Some Suggestions for Future Research." *Review of Environmental Economics and Policy* 3.1, pp. 4–21.

Hope, Chris (2011). "The PAGE09 Integrated Assessment Model: A Technical Description." *Cambridge Judge Business School Working Papers* 4.11.

Hurley, Jeremiah, Emmanouil Mentzakis, and Marjan Walli-Attaei (2020). "Inequality aversion in income, health, and income-related health." *Journal of Health Economics* 70, p. 102276.

Johansson-Stenman, Olof, Fredrik Carlsson, and Dinky Daruvala (2002). "Measuring Future Grandparents' Preferences for Equality and Relative Standing." *The Economic Journal* 112.479, pp. 362–383.

Kolstad, C., K. Urama, J. Broome, A. Bruvoll, M. Cariño Olvera, D. Fullerton, C. Gollier, W. M. Hanemann, R. Hassan, F. Jotzo, M. R. Khan, L. Meyer, and L. Mundaca (2014). *Social, Economic and Eethical Concepts and Methods*. Tech. rep. *in* Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel, J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Kornek, Ulrike, David Klenert, Ottmar Edenhofer, and Marc Fleurbaey (2021). "The social cost of carbon and inequality: When local redistribution shapes

global carbon prices." *Journal of Environmental Economics and Management* 107, p. 102450.

Kornek, Ulrike, Jan Christoph Steckel, Kai Lessmann, and Ottmar Edenhofer (2017). "The climate rent curse: New challenges for burden sharing." *International Environmental Agreements: Politics, Law and Economics* 17.6, pp. 855–882.

Kroll, Yoram and Liema Davidovitz (2003). "Inequality Aversion versus Risk Aversion." *Economica* 70.277, pp. 19–29.

Lessmann, Kai, Ulrike Kornek, Valentina Bosetti, Rob Dellink, Johannes Emmerling, Johan Eyckmans, Miyuki Nagashima, Hans-Peter Weikard, and Zili Yang (2015). "The Stability and Effectiveness of Climate Coalitions: A Comparative Analysis of Multiple Integrated Assessment Models." *Environmental and Resource Economics* 62.4, pp. 811–836.

McPake, Barbara, Delius Asiimwe, Francis Mwesigye, Mathias Ofumbi, Lisbeth Ortenblad, Pieter Streefland, and Asaph Turinde (1999). "Informal economic activities of public health workers in Uganda: implications for quality and accessibility of care." *Social Science & Medicine* 49.7, pp. 849–865.

Moreh, J. (1981). "Income Inequality and the Social Welfare Function." *Journal of Economic Studies* 8.2, pp. 25–37.

Nordhaus, William (2014). "Estimates of the Social Cost of Carbon: Concepts and Results from the DICE-2013R Model and Alternative Approaches." *Journal of the Association of Environmental and Resource Economists* 1.1/2, pp. 273–312.

— (2018). "Projections and uncertainties about climate change in an era of minimal climate policies." *American Economic Journal: Economic Policy* 10.3, pp. 333–60.

Nordhaus, William D. (2007). "A Review of the *Stern Review on the Economics of Climate Change*." *Journal of Economic Literature* 45.3, pp. 686–702.

Nordhaus, William D. (2011). "Estimates of the Social Cost of Carbon: Background and Results from the RICE-2011 Model." *NBER Working Paper* 17540.

Okun, Arthur M. (1975). *Equality and Efficiency: The Big Tradeoff*. The Brookings Institution, Washington, D.C.

Piacquadio, Paolo Giovanni (2017). "A Fairness Justification of Utilitarianism." *Econometrica* 85.4, pp. 1261–1276.

Piggott, John (1982). "The Social Marginal Valuation of Income: Australian Estimates from Government Behaviour." *Economic Record* 58.1, pp. 92–99.

Pirttilä, Jukka and Roope Uusitalo (2010). "A 'Leaky Bucket' in the Real World: Estimating Inequality Aversion using Survey Data." *Economica* 77.305, pp. 60–76.

Sezer, Haluk (2006). "Regional welfare weights for Turkey." *Journal of Economic Studies* 33.5, pp. 357–368.

Stern, Nicholas (2007). *The Economics of Climate Change: The Stern Review*. Cambridge University Press.

Stern, Nicholas H. (1977). *Welfare Weights and the Elasticity of the Marginal Valuation of Income*. *in* Artis and A. R. Nobay (eds.). Studies in Modern Economic Analysis: Procedings of the Annual Conference of the Association of Universitiy Teachers of Economics.

Tol, Richard S. J. (2010). "Imternational Inequity Aversion and the Social Cost of Carbon." *Climate Change Economics* 1.1, pp. 21–32.

Wagner, Gernot, David Anthoff, Maureen Cropper, Simon Dietz, Kenneth T. Gillingham, Ben Groom, J. Paul Kelleher, Frances C. Moore, and James H. Stock (2021). "Eight priorities for calculating the social cost of carbon." *Nature* 590.7847, pp. 548–550.

Weitzman, Martin L. (2007). "A Review of the *Stern Review on the Economics of Climate Change*." *Journal of Economic Literature* 45.3, pp. 703–724.

Young, H. P. (1988). "Distributive justice in taxation." *Journal of Economic Theory* 44.2, pp. 321–335.

Young, H. Peyton (1990). "Progressive Taxation and Equal Sacrifice." *The American Economic Review* 80.1, pp. 253–266.

On-line Appendix

A Mathematical details

A.1 The leaky-bucket method

To compute the parameter in the leaky-bucket method, substitute income y_i for consumption c_i in the social welfare function Eq. (1). Individual with income y_1 receives a leaky transfer from individual with income y_2. Leakage rate of the transfer is λ. Differentiating the function along a social indifference curve and solving for η yields:

$$y_1^{-\eta} \cdot (1-\lambda) + y_2^{-\eta} \cdot (-1) = 0 \quad \Rightarrow \quad \eta = \frac{\ln(1-\lambda)}{\ln\left(\frac{y_1}{y_2}\right)}. \tag{I}$$

For a given leakage rate λ that is socially tolerated, the lower the initial inequality between the two agents is (higher income ratio), the higher social aversion to inequality will be. From the opposite perspective, a given η means that society will tolerate higher leakage when the two individuals become more unequal.

A.2 The equal sacrifice method

For the equal sacrifice method, utility of individuals is $\frac{y_i^{1-\eta}}{1-\eta}$, with y_i their income, and η the normative inequality aversion parameter.

To estimate η, let τ be the income-tax function and k the absolute sacrifice.

Equal sacrifice means:

$$\frac{y_i^{1-\eta}}{1-\eta} - \frac{(y_i - \tau(y_i))^{1-\eta}}{1-\eta} = k\,, \quad \forall i\,. \tag{II}$$

Simple differentiation gives us an equation to estimate η from the underlying tax data (see Evans, 2008, for details on the derivation of this result):

$$\eta = \frac{\ln(1-\tau'(y_i))}{\ln\left(1-\frac{\tau(y_i)}{y_i}\right)}\,. \tag{III}$$

The η-parameter is a function of the marginal and the average tax rate.

A.3 Correcting for income inequality aversion

Almost all the revealed-ethics literature analyzes aversion to income inequality. At the same time, welfare economics and especially climate analysis use consumption as the key factor in social welfare. Can we use an estimate of income inequality aversion to evaluate consumption inequality? While much of the literature suggests that we can (Evans et al., 2005; Evans and Sezer, 2005; Tol, 2010; Groom and Maddison Pr., 2019), most of the studies in question are silent on this issue, with the exception of Stern (1977). The two parameters only provide the same information if consumption is a constant ratio of income (Stern, 1977). Hence, if savings rates do not vary with income, estimates based on income could be used in social welfare functions with consumption as the argument. Within countries, however, savings rates generally do increase with income (Dynan et al., 2004), even if the relationship is less clear between countries (Aghevli et al., 1990; Deaton, 1992; Masson et al., 1998). We now discuss ways of using or correcting inequality aversion that has been estimated from income data in a social welfare function evaluating how much agents consume.

Consider a set of agents and their individual consumption levels. Society wishes to evaluate the allocation of consumption but all it has to go on is income inequality

aversion. Once the relationship between income and consumption has been established, derived for example from Pinkovskiy and Martin (2009), the amount that agents consume can be converted into how much they earn. The allocation in income derived in this way can then be evaluated with the social welfare function (1) formulated in terms of income and the known facts about inequality aversion.

A similar approach enables us to derive an η estimate in (1) from the estimate based on income inequality. Assume the following to be true of the decision-maker in the respective experiment (survey participant, society): While choices were being made about income allocations, the decision-maker knew from their income how much each agent consumed and evaluated the corresponding allocations in terms of consumption. The social welfare function in terms of income can then be converted to the present function in terms of consumption with the correct relationship between income and consumption. Denote this relationship as $y(c)$. Insertion in the social welfare function yields:

$$W(\dots, c_i, \dots) = \sum_i \frac{y(c_i)^{1-\eta_y}}{1-\eta_y} \,, \tag{IV}$$

with η_y the estimated income inequality aversion. Then, consumption inequality aversion is given by:

$$\eta = \left(\eta_y \frac{y'(c)}{y(c)} - \frac{y''(c)}{y'(c)} \right) c \,. \tag{V}$$

Hence, if we know the relation between income and consumption for the experimental data, we can calculate consumption inequality aversion.

To expand on these insights, assume that income follows from consumption with a constant elasticity: $y = Kc^{\zeta}$. If $\zeta = 1$, then individuals will have a constant savings rate. Where $\zeta > 1$, the savings rate will increase with income. We then have:

$$\eta = \eta_y \zeta - \zeta + 1 \tag{VI}$$

Where $\zeta = 1$, $\eta = \eta_y$ will follow. If $\zeta > 1$, consumption inequality aversion is greater than income inequality aversion if $\eta_y > 1$ and vice versa ($\eta \gtreqless \eta_y \Rightarrow \eta_y \gtreqless 1$)

The reason for the sign-switch can be illustrated with reference to the leaky bucket experiment. Where $\zeta > 1$, individuals are less unequal when measured in terms of consumption than when measured in terms of income. However, there will also be less consumption lost because savings will absorb some of the leakage that takes place in transfer. These are two opposite effects: inequality aversion decreases because the leakage rate is lower and increases because the income ratio is higher. If $\eta_y > 1$, the second effect outweighs the first: decision-makers will tolerate a certain leakage rate even if there is lower inequality, hence their inequality aversion is larger. The reverse holds for $\eta_y < 1$.

An alternative approach does not neglect the fact that with savings some of the leakage is absorbed by future consumption. To make this explicit, consider a transfer $d\ell$ of income taken from a rich person and given to a poor person (leakage rate λ). Only the rich person will save. The transfer not only reduces current consumption on the part of the rich person, it also reduces future consumption in accordance with that person's savings rate. For the sake of argument, assume that current and future consumption are evaluated on the basis of the same inequality aversion and that future social utility is weighted by a pure time-preference rate ρ. Along a social indifference curve, we have:

$$0 = c_1^{-\eta} d\ell(1-\lambda) - c_2^{-\eta} d\ell(1-s) - \frac{(c_2(1+g))^{-\eta}}{1+\rho} d\ell s(1+r)\,, \qquad \text{(VII)}$$

where s represents the savings rate of the rich person, c_1 and c_2 the current consumption of the poor and the rich person respectively, g the consumption growth rate, and r the interest rate. Recall that along an optimal consumption path (Ramsey rule) $1+r = (1+\rho)(1+g)^{\eta}$. Then (VII) becomes:

$$0 = c_1^{-\eta}(1-\lambda) - c_2^{-\eta} \quad \Rightarrow \quad \eta = \frac{\ln(1-\lambda)}{\ln\left(\frac{c_1}{c_2}\right)}\,. \qquad \text{(VIII)}$$

Comparing this to Eq. (I), we see that taking account of the dynamic effect of the transfer leads to a higher estimate of consumption inequality aversion than the es-

timate reported in the studies because inequality in consumption is lower than inequality in income. If life-time consumption is evaluated by the decision-makers as outlined above, the estimates from the leaky bucket experiments would produce lower bounds for η to be used in (1).

B Additional information

B.1 Queries

Date: October 25, 2019 (update: October 26, 2020)

Query via Web of Science:

TS=((estimat* OR measur* OR reveal* OR parameter*) AND ((avers* NEAR/1 (inequality OR inequity)) OR ("social welfare function" AND inequality) OR ((preference* OR attitude*) NEAR/1 (equality OR equity))) OR (marginal NEAR/1 (valu* OR utility) NEAR/1 (income OR consumption)) OR ("leaky-bucket experiment") OR ("elasticity of marginal utility") OR ("equal sacrifice" AND taxation))

Query via Scopus:

TITLE-ABS-KEY((estimat* OR measur* OR reveal* OR parameter*) AND ((avers* W/1 (inequality OR inequity)) OR ("social welfare function" AND inequality) OR ((preference* OR attitude*) W/1 (equality OR equity))) OR (marginal W/1 (valu* OR utility) W/1 (income OR consumption)) OR ("leaky-bucket experiment") OR ("elasticity of marginal utility") OR ("equal sacrifice" AND taxation))

B.2 Additional figure

We have plotted the estimates according to each author in Fig. I to check for potential author bias. If a study has been carried out by several authors, each one is associated with the estimates. While there is no significant bias, some exceptions should be mentioned. We see that for the equal-sacrifice method, high estimates are mainly provided by Piggott. Pirttilä and Uusitalo provide two very different ranges

with the leaky-bucket method. Evans provides quite a high range throughout all his estimates (between zero and three).

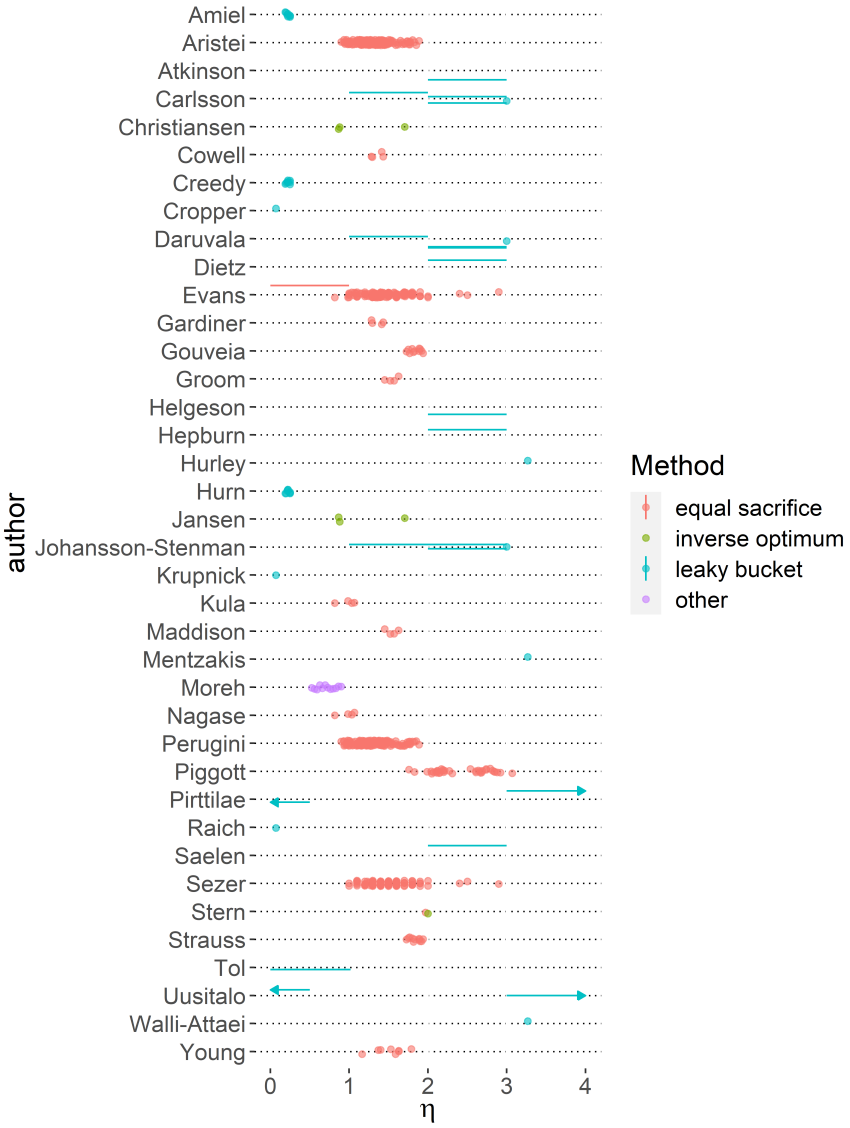

Figure I: Estimates according to each author

References

Aghevli, Bijan B., James M. Boughton, Peter J. Montiel, Delano Villanueva, and Geoffrey Woglom (1990). *The Role of National Saving in the World Economy: Recent Trends and Prospects*. Vol. 67. International Monetary Fund.

Deaton, Angus (1992). *Understanding consumption*. Oxford University Press.

Dynan, Karen E., Jonathan Skinner, and Stephen P. Zeldes (2004). "Do the Rich Save More?" *Journal of Political Economy* 112.2, pp. 397–444.

Evans, D., E. Kula, and H. Sezer (2005). "Regional welfare weights for the UK: England, Scotland, Wales and Northern Ireland." *Regional Studies* 39.7, pp. 923–937.

Evans, David (2008). "The marginal social valuation of income for the UK." *Journal of Economic Studies* 35.1, pp. 26–43.

Evans, David J. and Haluk Sezer (2005). "Social discount rates for member countries of the European Union." *Journal of Economic Studies* 32.1, pp. 47–59.

Groom, Ben and David Maddison Pr. (2019). "New Estimates of the Elasticity of Marginal Utility for the UK." *Environmental and Resource Economics* 72.4, pp. 1155–1182.

Masson, Paul R., Tamim Bayoumi, and Hossein Samiei (1998). "International Evidence on the Determinants of Private Saving." *The World Bank Economic Review* 12.3, pp. 483–501.

Pinkovskiy, Maxim and Xavier Sala-i Martin (2009). "Parametric Estimations of the World Distribution of Income Report No. 0898-2937." *National Bureau of Economic Research Working Paper*.

Stern, Nicholas H. (1977). *Welfare Weights and the Elasticity of the Marginal Valuation of Income*. *in* Artis and A. R. Nobay (eds.). Studies in Modern Economic Analysis: Procedings of the Annual Conference of the Association of Universitiy Teachers of Economics.

Tol, Richard S. J. (2010). "Imternational Inequity Aversion and the Social Cost of Carbon." *Climate Change Economics* 1.1, pp. 21–32.