Inequality Aversion for Climate Policy

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Introduction

The past few decades have seen the development of a sizable body of theoretical and modeling literature exploring the effect of inequality aversion—the idea that a society is willing to give up some material benefits or economic efficiency to achieve greater equality—on estimates of the social cost of carbon (SCC) and optimal climate policy (Azar and Sterner 1996; Anthoff, Hepburn, and Tol 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, inequality is considered in calculating the SCC, which refers to various estimates of the costs that carbon emissions impose on society as a whole. Both the original UK SCC estimate (Clarkson and Deyes 2002) and the estimate from the German Environment Agency (*Umweltbundesamt*; Astrid and Bünger 2019) have incorporated inequality aversion in their approach by using equity-weighted SCC estimates.

How much equity are people willing to pay for—in the sense of giving up something? Any equity-weighting approach must make a choice regarding the level of inequality aversion to be used in the analysis. Previous papers have shown that the choice of the level of inequality aversion can be as important as the much-discussed choice of discount rate—the rate used to determine the present value of future costs and benefits (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, whereas modeling literature often selects inequality-aversion levels either based on ad hoc choices or by examining how sensitive the results are to different choices of the inequality level.

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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 use inequality-aversion principles in their analysis.

We estimate inequality aversion for climate policy by adopting the constant relative inequality-aversion social welfare function, following Atkinson (1970). Inequality aversion, as used in this literature, is captured by a normative parameter in the social welfare function.[1] This parameter controls the degree to which a social planner is willing to trade higher total consumption of goods and services for a more equal distribution of consumption. To some extent, it is similar to a risk-aversion parameter in an expected-utility framework. In that framework, the utility (individual welfare) that an individual can expect depends on uncertain payoffs; because individuals have different degrees of tolerance for risk, the risk-aversion parameter captures 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—in other words, the underlying principle is normative or values based.

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 reasonable ranges of inequality aversion, and this literature forms one of the two lines of evidence that we review in this article (Pigou 1912; Dalton 1920; Fleurbaey and Michel 2001; Buchholz and Schumacher 2010; Fleurbaey and Maniquet 2011; Piacquadio 2017).

The second line of evidence uses empirical data to infer inequality-aversion values; this is the "revealed-ethics" approach. Examples include studies attempting to infer the inequality-aversion parameters that would, for example, justify the progressive income tax schedules that are observed in some jurisdictions (e.g., Stern 1977; Groom and Maddison 2019) or explain choices in income-distribution experiments (e.g., Amiel, Creedy, and Hurn 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." The implicit assumption underlying these approaches is that existing policies reflect what people believe is "good," or what "should" be done. From a philosophical point of view, this is a heroic assumption. It is entirely possible that all existing public policies that we observe are bad from an ethical point of view. In that case, all we are doing by inferring inequality-aversion levels from observed policies is perpetuating bad policies.

[1]There is another body of literature on inequality aversion in preferences (Fehr and Schmidt 1999). This has no bearing on our topic.

When an inequality estimate is derived from observed policies, the mechanism that underpins the estimate depends on the political institutions that lead to these policies. It is important to keep in mind that estimates based on policies ultimately reflect how the power of governing bodies is balanced within a country. Although existing policies are not necessarily good policies, 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 nonclimate areas are not necessarily bad and may reflect social preferences, such as when they emerge through democratic processes. Such policies may thus 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 in other areas, such as income taxation.

Inequality aversion in a social welfare function can control two different types of inequality: inequality in consumption at different points in time (i.e., the prescriptive discounting debate) and inequality at any given point in time. Following Anthoff and Emmerling (2019), we refer to inequality aversion over time as intertemporal inequality aversion and to inequality aversion at one point in time 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., Arrow et al. 2014; van der Ploeg 2020); we largely leave out this strand of the literature. One appealing normative stance is that inequality between individuals at any given point in time and between individuals at different points in time should not be evaluated differently—that is, one should use the same value for intertemporal and intratemporal inequality aversion. The argument extends to inequality between individuals in different uncertain states of the world. If one espouses this viewpoint, then our review of intratemporal inequality aversion adds to the literature on intertemporal inequality aversion as well and also informs values of risk aversion.

If one chooses not to treat people the same across space, time, and uncertain states of the world, this raises a complication in the climate economics literature. The issue is that the most commonly used social welfare function uses one parameter that controls not only 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 risk aversion from intertemporal elasticity of substitution; the latter reflects the degree to which people trade present consumption for future consumption. Similarly, 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. Because 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 of the other two concepts.

Our systematic review of the literature identifies 24 studies that provide inequality-aversion estimates based on the revealed-ethics approach and three studies based on the axiomatic approach. We find that all inequality-aversion estimates are positive—societies are willing to trade

off some other benefits to decrease inequality—with a single exception (Pirttilä and Uusitalo 2010). None of the three axiomatic studies provide an upper bound or maximum for inequality aversion.

For the revealed-ethics literature, we observe that estimates of inequality aversion are consistently above or below one (on a scale of zero to four, where zero means no aversion to inequality), 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 recipients, 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.

Framework

Social Welfare Function

Income redistribution counteracts inequality in nearly all countries, demonstrating the role that inequality aversion plays in social welfare. In economics, social welfare functions provide a basis for choosing optimal levels of inequality—in other words, how to balance reduced inequality against consumption for society as a whole.

There is extensive research on how to measure inequality (see reviews by Chakravarty 1990; Sen and Foster 1997; Silber 1999). Dalton (1920) noticed that, under some assumptions (additive and symmetric individual metrics), an inequality index corresponds to a specific social welfare function. Atkinson (1970) provided a landmark in this literature by interpreting inequality as a loss to the welfare of a society. The Atkinson index gives, in percentage points, how much total income can be sacrificed without losing welfare, if people have the same income (perfect equality of income is used as a baseline). He explored different normative assumptions on inequality indices, including the prominent "scale-invariance" index, which requires the inequality index to be neutral to proportional shifts in the distribution of income—in other words, the level of inequality aversion does not change in response to multiplying all incomes by the same number. With the scale-invariance requirement, Atkinson obtained a constant relative inequality-aversion social welfare function. We adopt this type of function here:[2]

$$W(c_1, \ldots, c_N) = \sum_{i=1}^{N} \frac{c_i^{1-\eta}}{1-\eta}, \tag{1}$$

where η is society's inequality aversion and c_i is the level of individuals' consumption of goods and services. The curvature of the social welfare function represents the social planner's inequality aversion in the following sense: when an individual's consumption increases by 1 percent, marginal social welfare decreases by η percent. When η equals zero, social welfare equals total consumption, whereas social welfare approaches minimal consumption across individuals when η tends toward infinity (Atkinson 1970).

[2]When $\eta = 1$, we use the alternative form $W(c_1, \ldots, c_N) = \Sigma_{i=1}^{N} \ln(c_i)$.

Optimal climate policy and SCC estimates based on a social welfare function (or, equivalently, using equity weights) are largely derived using equation (1) as a default or important benchmark (Azar and Sterner 1996; Anthoff, Hepburn, and Tol 2009; Dennig et al. 2015; Lessmann et al. 2015; Adler et al. 2017; Anthoff and Emmerling 2019; Astrid and Bünger 2019). An overview of alternative criteria used in climate economics can be found in Botzen and van den Bergh (2014). Our purpose is to inform the academic community and policy makers of the considerations involved in choosing a value for the parameter controlling inequality aversion. We then follow the tradition of considering a constant value for inequality aversion throughout the entire range of consumption values, from low to high levels of consumption. Another question, beyond the scope of the article, is whether social preferences can be represented by the social welfare function in equation (1). Empirical social choice methods can be used to answer this question (see Gaertner and Schokkaert 2012; Venmans and Groom 2021).

In our setting, society does not place a value on how much people consume over time or how much they consume 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 social welfare function thus disregards individual characteristics beyond consumption so that we avoid inequality aversion that is context specific. Richer analysis, beyond the scope of the article, could incorporate people's needs (Atkinson and Bourguignon 1987), altruistic or other-regarding preferences (Fehr and Schmidt 1999; Bergstrom 2006), and the unequal distribution of environmental goods (Venmans and Groom 2021).

We next turn to how inequality aversion may be measured. The revealed-ethics literature almost exclusively measures income inequality aversion instead of consumption inequality aversion. In other words, these studies replace how much people consume with how much they earn in equation (1) and estimate the η-parameter (the level of inequality aversion) based on a social preference that is more concerned with consumption of goods and services than with income. Income and consumption inequality aversion coincide if the saving rate is constant across income levels (Stern 1977); however, poor households are more likely to spend income promptly on necessities such as food rather than saving money. See appendix A.3 (appendixes A and B are available online) for more details and ways of correcting for estimates of η based on income if the savings rate varies with income.

Empirical Strategy

For our review, we have drawn upon two academic literature databases: Web of Science and Scopus (see appendix B.1 for the exact terms of the query).[3] 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 24 publications estimating inequality aversion based on revealed ethics, that is, using data derived from policy choices. These 24 papers include studies cited

[3]Our analysis is limited to peer-reviewed literature and excludes any reports or similar publications that estimate inequality aversion. See ISA (2022) for an interesting report that estimates η based on member contributions to the United Nations budget.

in the literature but absent from the literature databases. We disregarded all studies estimating consumption or income elasticities of utility (the proportional responsiveness of utility to proportional income changes) that were based on consumer demand, savings, and other dynamic decisions. These omitted studies have to do with intertemporal consumption smoothing (the tendency to even out consumption over time) or are based on risk aversion only.

From the 24 studies, we extracted 435 estimates for the inequality-aversion parameter η. Many studies provide more than one estimate, based on different samples (e.g., 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 ethical axioms.

Revealed Ethics: Choice, Methods, and Data

The revealed-ethics literature uses different empirical strategies to estimate values or ranges for the inequality-aversion parameter 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; their choices have no real-world consequences. This approach is grounded in empirical social choice, where the use of the social welfare function in equation (1) is informed by the opinion of the public through questionnaires (Gaertner and Schokkaert 2012). Haveman and Freeman carried out pioneering work on the empirical ethics that are implicit in benefit–cost analysis for water projects (see Banzhaf 2009). Hypothetical choices are based on stated preferences. This is an example of the "contingent-valuation" methods that environmental economists use to estimate the value of nonmarketed goods and services, such as a clean environment; they are subject to well-known biases (Diamond and Hausman 1994). Estimates based on actual choices use real-world data from choices that have been made. Actual choices, based on revealed preferences, are not immune to biases. In particular, data from a country's tax schedule are the result of political power and bargaining and should be used with care even if tax schedules are the result of democratic processes. Furthermore, if respondents or voters perceive their government as corrupt, estimates may reflect distrust.

The second dimension is what we call "method." It represents a distinct conceptual framework for estimating inequality aversion, with its own underlying principles and assumptions. The estimates are mostly based on the categorization of methods into "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 distribution, 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 (available online) 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 \$1 from an individual with income of \$5,000 to an individual with income of

$1,000. The transfer is leaky, meaning that part of the dollar is lost (e.g., to administrative costs). As a result, 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 enables us to directly estimate income inequality aversion. The estimate depends on the income ratio and the leakage rate; please see 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 (from person A to person B). The hypothetical choice experiment defines a transfer of funds from one person to another 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, Creedy, and Hurn 1999; Pirttilä and Uusitalo 2010; Cropper, Krupnick, and Raich 2016).

We have termed the second type of data "income distribution." Respondents are presented with distributions of income featuring different levels of inequality and average income levels. They are 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 of income are therefore implicitly leaky. The inequality-aversion parameter can be inferred from the choices made (Johansson-Stenman, Carlsson, and Daruvala 2002; Carlsson, Gupta, and Johansson-Stenman 2003; Carlsson, Daruvala, and Johansson-Stenman 2005; Atkinson et al. 2009; Hurley, Mentzakis, and Walli-Attaei 2020).

Note that the income-distribution category may correspond to three different types of data. Hurley, Mentzakis, and Walli-Attaei (2020), for example, explicitly refer to the national distribution of income in Canada. Others, such as Johansson-Stenman, Carlsson, and Daruvala (2002) and Carlsson, Daruvala, and Johansson-Stenman (2005), refer to a hypothetical society in which an imaginary grandchild lives. Finally, Atkinson et al. (2009) consider the distribution of income on a 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 one of the societies from which they choose so that they may choose a society with less inequality to hedge against their private income uncertainty—the risk that they or a descendant may end up in the lower part of an unequal income distribution. Carlsson, Daruvala, and Johansson-Stenman (2005), Atkinson et al. (2009), and Hurley, Mentzakis, and Walli-Attaei (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, we provide 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 consumption, 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. This is the trade-off in which high taxes—which are redistributed to lower-income people—encourage potential workers to do less taxable work. When inequality aversion is higher, a social planner is willing to accept a higher efficiency loss from an income tax model that discourages work to achieve a distributional objective. The studies that use the inverse-optimum approach reverse this procedure and ask 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 not only reduces inequality but also distorts work incentives and thus leads to social welfare loss.

Table 1 Leakage of international development aid and derived inequality-aversion estimates

Source	% 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, Johannesen, and Rijkers (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	Uganda	World Bank	
Asiimwe et al. (1997)	78	Drugs	Uganda	Central government and external donors	
McPake et al. (1999)	76	Drugs	Uganda	Central government and external donors	
Average	79				

Note: Leakage is reported as percentage lost during the transfer.

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—that is, 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 equation (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 income sacrifice made by taxpayers is quantified using a utility function (Young 1990). The utility function here represents a social norm and has the constant relative inequality-aversion form discussed above. 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 schedule. (See appendix A.2 for the formula.)

This equal-sacrifice principle has been used not only on different types of data, most frequently on actual choices via "income taxation" (Piggott 1982; Sezer 2006; Groom and Maddison 2019), but also on hypothetical income taxation (Evans, Kula, and Nagase 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: that there is a constant decline in income inequality as measured by the Atkinson index. Because the Atkinson index is based on our social welfare function, equation (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.

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 fulfill a number of normative principles. They include the Pigou–Dalton principle (Pigou 1912; Dalton 1920; Fleurbaey and Maniquet 2011; Piacquadio 2017), proportional transfers (Fleurbaey and Michel 2001), and solidarity (Buchholz and Schumacher 2010). Limits to inequality aversion can be directly inferred.

Comparing Estimates from Revealed Ethics and Normative Principles

Estimates of inequality aversion based on the different revealed-ethics methods—leaky-bucket, inverse-optimum, and equal-sacrifice methods and constant decline in inequality—are comparable with some degree among each other and also are comparable with estimates based on the axiomatic approach. All approaches share the feature of measuring the curvature of the social welfare function in equation (1); remember that a higher curvature indicates a higher inequality

aversion. For alternative social welfare functions, see Amiel, Creedy, and Hurn (1999). Knowing the preferences of society, climate policy, and SCC estimates based on equation (1) would 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 comparing income allocations. It assumes that preferences revealed by a society's policies can be represented by the social welfare function, equation (1). The inverse-optimum method also assumes that social preferences can be represented by equation (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 as a function of income by the constantly elastic form in equation (1) and is a representation of utility for the normative analysis of taxation (Young 1990). As 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 (2019), and others.

Moreh (1981) and the axiomatic literature (Pigou 1912; Dalton 1920; Fleurbaey and Michel 2001; Buchholz and Schumacher 2010; Fleurbaey and Maniquet 2011; Piacquadio 2017) use different assumptions about how governments influence inequality. These include constant decline in inequality over time, the proportional-transfer principle (explained in "Axiomatic Literature"), and others. Assuming that preferences on inequality can be represented by equation (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). The Pareto principle guarantees that it is impossible to make someone better off without making someone else worse off. Second, the equal-sacrifice method differs from the leaky-bucket experiment in its assumptions about social preferences, because the equal-sacrifice method follows from additional axioms about redistributive justice. Third, the leaky-bucket experiment implies a loss by one of the parties and has been criticized for being subject to loss aversion—when people are more unhappy about losing a given amount than they are pleased to gain the same amount (Venmans and Groom 2021).

Results and Discussion

Revealed Ethics

Estimates of inequality aversion from the revealed-ethics literature

Estimates of inequality aversion from the revealed-ethics literature are plotted in figure 1. The estimates are expressed in terms of the three dimensions discussed above: choice, method, and data. The y-axis represents the type of data used, and the x-axis represents the value of the inequality-aversion parameter, ranging from zero to four. Zero represents no inequality aversion, and four represents strong inequality aversion. An arrow represents an undefined bound. We

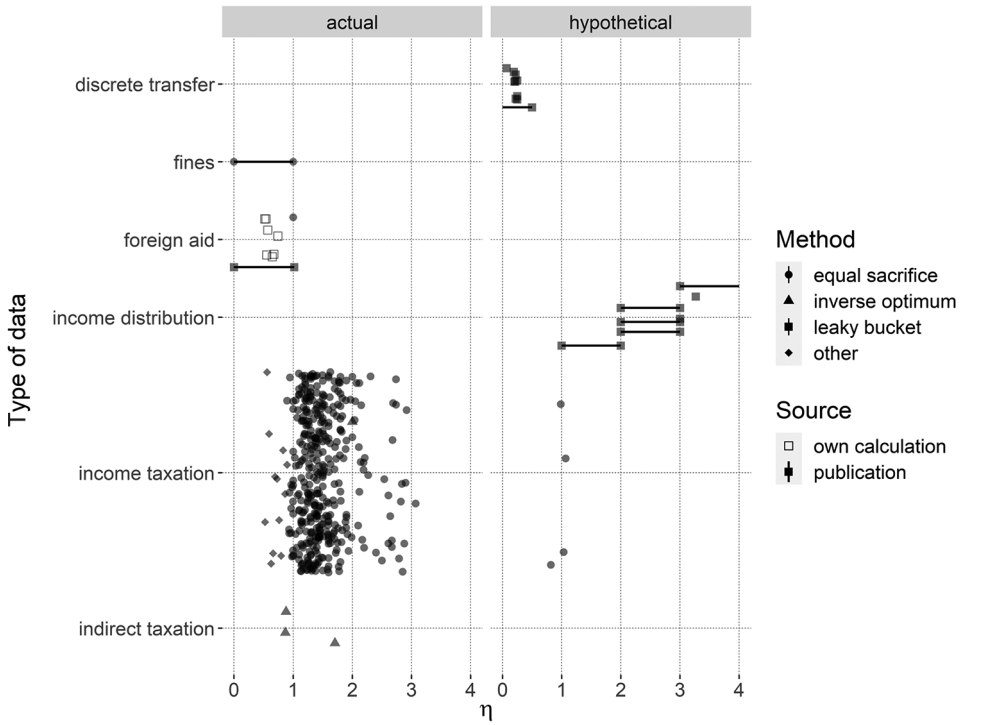

Figure 1 Inequality-aversion estimates in terms of choice, method, and data. Data are available in the supplementary material (available online).

divide estimates according to actual (left) and hypothetical (right) choices. Each shaded symbol stands for a different method.

From figure 1, we first observe that, for a given combination of method and data type, estimates tend to cluster around certain defined values or ranges. There 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 figure 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. For discrete transfers, fines, and foreign aid, we observe values of one or lower for η. In other words, 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. Greenhouse gas emission reductions are a global public good, affecting individuals across countries. This means that inequality between countries is a main driver affecting SCC estimates (Anthoff, Hepburn, and Tol 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 United States as a transfer to developing countries and uses this as a basis for its inequality-aversion choice in figure 1, the somewhat lower inequality aversion would be chosen by the decision makers, compared with 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 United States compared with higher inequality aversion. If this lower level of inequality aversion is used in a benefit–cost analysis of US climate policies, this lower aversion parameter would decrease US climate efforts.

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

The observation that type-method pairs are placed on either side of the value $\eta = 1$ marks an interesting threshold. An inequality-aversion level of one translates to a one-to-one proportionality 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 (where tax burdens are disproportionately higher at higher incomes), whereas regressive policies (placing a disproportionate tax burden on lower-income earners) are socially preferable when $\eta < 1$.

Why do we observe such a division in our data? One difference between data types that produce high values of inequality aversion (income distribution, income taxation, indirect taxation) and data types that produce 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. We might suspect the influence of loss aversion in this setting (Kahneman and Tversky 1979; Venmans and Groom 2021). For discrete transfers, the donors are explicitly singled out—one knows who will lose something. 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 evaluate global inequality, whereas data with high inequality aversion describe inequality within countries. From a theoretical perspective, this is not absurd. Within-country redistribution may be seen as a social contract providing people with a better society. It follows people's preferences. On the contrary, foreign aid captures people's altruism or indirect interest (stability of the world), which might not be as strong as the preference toward oneself or one's own society. 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 arguably outweighed by the fact of not explicitly knowing the donor-recipient constellation. Because climate policy has implications for global inequality, we produce more estimates of inequality aversion based on foreign aid below. (See appendix B.2 for an analysis of other possible drivers behind the different η estimates.)

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, Hepburn, and Tol

Table 2 η ranges from the axiomatic literature

Source	η range	Principle
Pigou (1912), Dalton (1920)	> 0	Pigou–Dalton
Fleurbaey and Michel (2001)	> 2	Proportional transfers
	≥ 1	Proportional transfers, ex post
Buchholz and Schumacher (2010)	> 1	Solidarity
	$= \infty$	Equality of consumption
	$= 1$	No-envy in absolute sense
	$= 2$	No-envy in relative sense

2009; Anthoff and Emmerling 2019). Figure 1 shows that there are very few estimates of η derived from foreign aid that directly inform inequality aversion between countries. Accordingly, we introduce 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 tests only a range of leakage rates (from 0 to 95 percent), stating that actual leakiness cannot be observed. To make Tol's estimates more precise, we review the international leakage rates referred to 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 20 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 $\eta = 0.385$ in 2005 to $\eta = 0.554$ in 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 are available in the supplementary material.) Our estimates are slightly higher in comparison with Tol (2010). When leakage is above 90 percent, η is about 0.7. 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, whereas 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.

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 evidence on ranges for η found in the peer-reviewed literature. Not all contributions report levels directly. Therefore, where appropriate, we apply the results of these contributions to our social welfare function in equation (1). The estimates are summarized in table 2.

The axioms in this line of evidence consider transfers made between unequal populations. Equity principles then postulate that a certain type of transfer, which we detail below, enhances social welfare. The axiomatic literature infers the level of inequality aversion necessary so that the equity principles hold.

First, there is the Pigou–Dalton principle (Pigou 1912; Dalton 1920; Fleurbaey and Maniquet 2011; Piacquadio 2017). A transfer from a rich person to a poor person that does not reverse their order in the distribution reduces inequality and enhances social welfare. A social criterion

satisfying this principle has to be strictly concave; that is, it has to exhibit inequality aversion so that η is positive.

Fleurbaey and Michel (2001) analyze the principle of proportional transfers. The principle states that social welfare is increased when the consumption of a rich person or country is reduced by a certain percentage while the consumption of a poor person or country 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 larger than or equal to one.

Buchholz and Schumacher (2010) consider equity principles in the context of an intergenerational transfer. Two generations are aggregated with the same functional form as in equation (1). In a productive economy, and for each dollar of consumption forfeited by the current generation, the future generation consumes a value of more than a dollar. We reinterpret their model and consider a leaky transfer from a donor country (the future generation) to a recipient country (the current generation). The first equity principle in Buchholz and Schumacher (2010) is called solidarity: when leakiness is reduced, both countries should be better off in the allocation that maximizes social welfare. Following this principle, η should be greater than one. The other principles they study are based on absence of envy between the two countries. That means, at the allocation that maximizes social welfare, neither country is predicted to desire swapping positions with the other. In the strictest sense, envy is absent when both countries consume the same amount. Then, η should be infinite. However, Buchholz and Schumacher (2010) argue that, because of the asymmetry between the two entities (investment in their model, leakiness, here), the recipient country should consume less than the donor country. The principle of no-envy in an absolute sense implies that consumption in the donor country is proportional to consumption in the recipient country. In this case, η should be one. Last, the principle of no-envy in a relative sense implies that relative consumption of the donor is proportional to relative consumption of the recipient. 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 larger than or equal to one.

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. Integrated assessment models combine physical and social science perspectives to describe possible climate change scenarios. Azar and Sterner (1996) analyze a continuous range between zero and three. Anthoff, Hepburn, and Tol (2009) frame their scenarios along the values 0.5, 1, and 2. 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 equal to 2, and Kornek et al. (2021) use values of 0.5, 1, 1.5, and 2. Anthoff and Emmerling (2019) assume a central value of 0.7 and apply a continuous range between 0 and 1.5. 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). 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 German Environment Agency (*Umweltbundesamt*) officially adopted an equity-weighted SCC that also uses an inequality-aversion value of one (Astrid and Bünger 2019). When the United States adopted its official SCC estimate in 2010, it did not use equity weighting. The Trump administration changed the official figure to a domestic SCC—that is, one where impacts outside the United States receive no weight at all. The Biden administration early on reverted to the Obama-era global SCC values that did not use equity weights and at the same time tasked a newly reconstituted Interagency Working Group with a comprehensive SCC update (US Interagency Working Group on Social Cost of Greenhouse Gases 2021). Although some have suggested that a future SCC update could use equity weights (Wagner et al. 2021), it is currently not known whether this recommendation will be picked up by the Interagency Working Group.

It is also informative to compare our results for intratemporal inequality aversion with values that have been proposed in the intertemporal inequality-aversion context. For benefit–cost analysis, the value of η is a main driver of the consumption discount rate, which is the trade-off between consumption now and consumption later (e.g., Arrow et al. 2014; van der Ploeg 2020). For example, in his review, Stern (2007, 628) uses an intertemporal inequality-aversion value of one. In reply, Nordhaus (2007) argues that η and the pure rate of time preference (again, the preference for present vs. future) should be determined 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 1.45 in updates of his DICE (Dynamic Integrated Climate-Economy) model (Nordhaus 2014, 2018). Weitzman (2007) suggests a value of 2, whereas, according to Dasgupta (2008), values between 1.5 and 3 are more reasonable. In its last assessment report, the Intergovernmental Panel on Climate Change proposes a consensus value between one and three (Kolstad et al. 2014). Again, all these values fall within the range of our systematic review.

Conclusions for Climate Policy

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. An inequality-aversion parameter of one 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, by demonstrating that it is not outside a plausible range. However, our review also supports different choices, which demonstrates the need to vary inequality aversion in climate-policy assessment to account for alternative moral stances.

Second, existing progressive income-taxation schedules in developed countries generally imply inequality-aversion values that are higher than one, somewhere in the range of 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). Our review suggests that such a choice can be justified by arguing that climate policy should be based on a level of inequality aversion that is similar to what we observe in some domestic income-taxation schedules or similar to income distributions favored by survey respondents. Using these higher values for inequality aversion has strong implications for climate policy. Take as an example a rich country with double the domestic income of a poor country. If the inequality-aversion level equals two, the hypothetical rich country should invest $100 if the benefits to the poor country are between $25 and $100. With a level of one, the rich country should not invest $100 unless the benefits to the poor country are $50–$100.

Third, policy contexts that cover foreign aid generally exhibit inequality-aversion values smaller than one. Thus, reducing inequality at the national level seems to 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). If climate policy is considered primarily as an international problem, with the aim of making climate policy consistent with other international policies that try to reduce global inequality through foreign aid, this line of evidence suggests that climate policy should use inequality-aversion estimates in the range of zero to one. 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 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. This suggests that the lower inequality-aversion values accurately reflect the limited weight that a society places on equality. On the other hand, it seems highly dubious from an ethical point of view to support a different inequality-aversion value for domestic policies, such as income taxation, and for international policies, such as 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 the level of inequality aversion in developing countries. 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. For example, there is no upper bound on inequality aversion based on

ethical principles. Last, our review has identified that different empirical strategies tend to give systematically higher or lower estimates of inequality aversion. For example, hypothetical leaky-bucket experiments via direct transfers tend to give low estimates, whereas 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.

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