Equity in climate–economy scenarios: the importance of subnational income distribution

Paul Baer

Woods Institute for the Environment, 371 Serra Mall, Stanford University, Stanford, CA 94305, USA
and
EcoEquity, 1514 Beverly Place, Albany, CA 94706, USA

E-mail: pbaer@ecoequity.org

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Abstract

It is widely accepted that climate change raises equity considerations, and this has been addressed in various explicit and implicit ways in scenario-based climate and climate-policy research. In this paper I look in particular at the IPCC’s well-known ‘Special Report on Emissions Scenarios’, in which equity is primarily quantified as the distribution of income between countries, and highlight the need for more explicit treatment of equity both within and across national borders. I apply an existing method for modeling subnational income distributions and show that this affects the results of welfare calculations of the type used in economic analyses of climate policy. Additionally, I suggest ways in which this kind of equity analysis could be applied to questions that address broader considerations of climate policy and development, such as burden sharing in the allocation of obligations, and conclude with remarks that frame the scenario development process in the context of what I call ‘the contested storyline of the present’.

Keywords: welfare, inequality, storylines, cost–benefit analysis, declining marginal utility of income, disaggregation, burden sharing

1. Introduction

While various forms of policy-relevant scenario analysis have been around for many years, the Special Report on Emissions Scenarios (Nakicenovic and Swart 2000) by the Intergovernmental Panel on Climate Change (IPCC) brought new visibility to the value and pitfalls of scenario-based research. The so-called ‘SRES’ scenarios have been by some standards quite influential, as they have provided an important and oft-cited basis for estimates of both the risks from plausible growth in GHG emissions, and the costs of adjusting the global energy economy to reduce those risks. Within a surprisingly large community of researchers and policy experts, the jargon terms of the SRES—for example, ‘A1B’ and ‘B1’ (see below)—have become widely used shorthand for different possibilities for the future.

The SRES—its a direct extension and updating of earlier IPCC work—is now a decade old, and efforts are underway to produce new scenarios to meet the evolving requirements of various user communities (Moss et al 2008). In this context, it is useful to reflect on the strengths and weaknesses of the SRES process and the scenarios it generated. My question is simultaneously very narrow and very broad: how should considerations of equity be incorporated into the creation and use of the next round of climate–economy scenarios? It is narrow inasmuch as, of the many intersections of ‘equity’ with the climate debate, the inclusion of equity concerns in scenario analysis is not perhaps among the...
most visible or, frankly, most important. And it is broad inasmuch as there are many quite distinct ways in which equity considerations do matter in scenario analysis, some very conceptual, some very narrowly quantitative.

As I will demonstrate below, the most important way in which equity is addressed in the SRES is in terms of the distribution of income between countries. To preview my main argument, I suggest that for a variety of reasons it is important to also include the distribution of income within countries in future climate–economy scenarios, both qualitatively and quantitatively. First, though I do not develop the argument here, I suggest that doing so is an important starting point for persons who think that one reason to consider equity in scenarios is to help make the world more equitable. Second, for studies of impacts, adaptation and vulnerability that are typically focused at the national or even subnational level, the distribution of income within countries will obviously be a crucial consideration. Third—and this will be my main focus—the inclusion of subnational income distributions will measurably and perhaps significantly change the outcome of efficiency-oriented policy analyses. It has already been demonstrated that disaggregating to countries instead of multi-country regions can more than double the calculated value of the ‘social cost of carbon’ (Anthoff et al. 2009); I offer evidence that disaggregating impacts within countries has a similar magnitude of impact. I show furthermore that this suggests reasons why it is important to consider trends in inequality within countries in the creation of scenario storylines.

2. On equity and climate change

It is commonplace now to note that the threat of anthropogenic climate change and the apparent need for a cooperative global response raise a variety of equity considerations. The UNFCCC itself famously states that parties should act ‘on the basis of equity and in accordance with their common but differentiated responsibilities and respective capacities’. The assessment reports of the IPCC have included chapters or subchapters that explicitly address equity since at least the Second Assessment Report (Banuri et al. 1996, Arrow et al. 1996), and those reports have an increasingly large and diverse literature to survey (e.g., Töth 1999, Adger et al. 2006). The most common themes in this literature have been intergenerational equity, largely but not exclusively focused on controversies about discount rates in cost–benefit analysis of climate change and climate policy (e.g., Portney and Weyant 1999), and international equity, focusing both on the fair allocation between countries of obligations to reduce emissions (e.g., Shue 1999), and the asymmetry between the highest emitters and the most vulnerable (Shukla 1999, Sagar and Banuri 1999). Procedural equity in the climate negotiations and broader policy domain has been a lesser but also noticeable concern (Shukla 1999).

Equity as the term is most broadly used refers to the fairness of some situation relative to a normative standard; that is to say, whether some action or outcome is equitable is a question of ethics. For this reason much of the literature which addresses ‘climate equity’ draws on the theoretical and applied writings of philosophers (for a good survey see Gardiner (2004)). There is also a subset that is rooted in social and environmental movements and critical social science (e.g., Lohmann 2006), as well as, again, a subset focused on economic analysis and discounting. For the purposes of this paper, I will restrict my attention largely to discussions of the SRES scenarios themselves and the economic literature, which typically has made use of the SRES or similar climate–economy scenarios.

Before addressing these questions, however, it is important to acknowledge that there is a general pattern that is reflected in the broad range of debates over climate policy and related questions of equity. To hugely oversimplify, both the political and academic worlds can be loosely divided into those who think the world is basically equitable as it is, and those who think that it is not. In politics, this is reflected in the classic ‘right–left’ distinction; in the scholarly or analytic domain, there is a parallel distinction between ‘mainstream’ approaches (especially but by no means limited to neoclassical economics and game theory) that largely accept the world as ‘fair enough’, and ‘critical’ or ‘radical’ perspectives that see the world as characterized by pervasive injustice. In philosophy one can see the same dichotomy in libertarian versus egalitarian approaches to distributive justice. Although this is a simplistic and subjective approach to an enormously complex set of issues, I believe that it is both a helpful and necessary starting place for a discussion of equity, scenarios and climate change, as this pattern can be seen reflected in debates about discounting, the allocation of emissions rights, and other dimensions of climate policy that involve distributive justice.

In the domain of climate scholarship in particular, in which the most prevalent contributors have been natural scientists and economists, authors who have a critical perspective have been a relative minority, and ‘equity’ has largely been framed as essentially a ‘preference’ or a matter of taste. That is to say, views about equity are usually described, rather than argued for (though the philosophical literature is a notable exception here). However, the nominally ‘objective’ perspective on equity, particularly in economics, embeds a variety of assumptions that are not ethically neutral. This is not a novel observation; if nothing else, this is shown in the numerous discussions on discounting the future (including the outpouring following the publication of the Stern Review of the Economics of Climate Change in 2006—see below). And indeed, some of the assumptions that lie behind discounting have implications for comparing the well-being of people alive at the same time—so-called ‘equity-weighting’—which has been explored by a few authors (Azar 1999, Tol 2001, Anthoff et al. 2009).

In particular, the formal structure of economic analysis that is used in a wide range of climate-policy studies (many of which draw directly on the SRES or similar scenarios as their ‘reference case’) is explicitly sensitive to distributive concerns inasmuch as the social value of a gain or loss is dependent on to whom it occurs. Thus, even making the distribution of income within countries explicit—indeed, of how one assumes it changes over time—will change the result of a
nominally objective economic analysis. Furthermore, though I can only gesture here at this issue, models which include causal pathways of indirect harm—‘externalities’ in the terminology of economics—will produce different ‘optimal’ policies depending on what assumptions are made about disputed rights, for example to protection from/compensation for the externalized harm of pollution.

I want to conclude this section by emphasizing a different but related point, which is that there is a need to consider and develop scenarios that draw attention to the non-climate policy and political choices we are now confronting globally. In a world in which poverty is still endemic and resources from fresh water to fisheries stocks are under increasing pressure, clearly climate change is only one of many concerns one might have about the equity and sustainability of the status quo. Indeed, one of the key questions that will need to be asked in the next round of scenario development is how debates about climate policy will be practically linked to broader debates about development, equity and sustainability (see Banuri and Weyant (2001) for an earlier discussion of these issues). The role of the ‘new scenario process’ in shaping the emerging debates is an open question, and an interesting one. Part of my purpose here is to suggest what some of the important links might be, and what choices this implies for scenario development. Before I turn to these questions, however, I will give a slightly longer review of the SRES process, products and follow-up, in light of some of the framing comments offered above.

3. Equity and the SRES scenarios

The SRES authors adopted an existing model (Garb et al (2008) call it ‘story and simulation’, after Alcamo (2001)) in which qualitative and descriptive storylines were developed first, then given multiple quantitative treatments by different groups using different modeling systems and auxiliary assumptions. The authors chose to define four storyline ‘families’, which were classified in a graphic along two axes, one opposing ‘economy’ to ‘environment’ and the other opposing ‘regional’ to ‘global’. The four storylines were placed in the quadrants thus defined and labeled by letter–number pairs: A1 and A2, B1 and B2. The A scenarios emphasized economic growth, the B scenarios sustainability and the environment; the I scenarios, globalization, the 2 scenarios, regional differentiation. (Interestingly, in the text of the SRES though not in the graphic, ‘equity’ is paired with ‘environment’ and opposed to ‘economy’ or ‘development’.) Additionally, the A1 family was divided into three subgroups known as A1T (clean ‘Technology’, low emissions), A1B (‘Balanced’ technology, medium emissions), and A1FI (‘Fossil Intensive’ technology, high emissions).

Given the primary purpose of IPCC-published scenarios—to provide a commonly accepted groundwork for subsequent climate and climate-policy studies, which could be used without controversy—it was necessary to step delicately around the political issues associated with equity, and handle it in a manner consistent with appropriate community standards of objectivity. In their overview the SRES authors claim that none of the four families are to be seen as preferred: ‘each storyline represents different demographic, social, economic, technological, and environmental developments, which may be viewed positively by some people and negatively by others’ (Nakicenovic and Swart 2000, Summary for Policymakers). Yet the authors could not avoid engaging with the real-world debates about equity that I alluded to above. Thus one way to interpret their choice of storylines is that the A1 scenario loosely represents the desired future of ‘neoliberals’ who prioritize market-driven economic growth, while the B1 scenario represents the desired future of ‘greens’—at least globally-oriented greens—who prefer deliberate efforts to achieve sustainability and greater equality. (Indeed, the other two scenario families—A2 and B2—seem to have very little to recommend them, as they have higher population, higher pollution, and lower incomes all around. The SRES authors describe their virtues in the language of ‘regional self-reliance’ but, frankly, it is hard to imagine that anyone would argue that, as interpreted in the SRES, the A2 or B2 worlds are more desirable than the A1 and B1 worlds.)

Because the distinction between the A and B scenarios was the prioritization of economic growth on the one hand and sustainability and ‘equity’ on the other, and the 1 scenarios had a globalizing orientation, one might have expected that the B1 scenario would have greater equality between rich and poor countries while the A1 scenario would have higher incomes in both rich and poor countries. In fact, however, the rate of ‘convergence’ between poor and rich countries is higher in A1 than B1, with the ratio of per capita incomes between the industrialized and developing countries falling from about 15 to 1 in 1990 to 2.8:1 in 2050 in the A1B scenario versus 3.6:1 in the B1 scenario (Nakicenovic and Swart 2000, Technical Summary).

While it would be interesting to speculate on the reasons and implications of this perhaps surprising result, (I use ‘result’ loosely because in fact these variations in per capita incomes were among the fundamental choices made by the authors in distinguishing the scenario families), it has received no previous attention in the literature that I am aware of. In contrast, what did receive criticism (Castles and Henderson 2003) was, first, that all of the scenarios had very high rates of convergence of per capita incomes between rich and poor countries3, and second, that the B scenarios, even though they did not quantitatively reflect greater equality of incomes, were asserted to reflect ‘improved equity’. The specific language used by Castles and Henderson is worth noting:

\[ \text{... it is taken for granted in the SRES, as also in the Report of WG III, that substantial differences in GDP per head across countries constitute ‘inequalities’: inequalities as such are viewed as unjust. This is, to put it mildly, a questionable presumption.} \]

Two points stand out here. First, while the SRES authors acknowledge that views of equity vary, they did

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3 Their critique is tied to a specific objection to the use of MER (Market Exchange Rate) data for GDP and per capita GDP rather than PPP (Purchasing Power Parity) adjusted data, which they asserted contributed to the overstating of economic (and thus emissions) growth in developing countries; see Van Vuuren and Alfsen (2006) for a discussion of this point.
The quantified scenarios that were developed under the SRES umbrella, and the many similar scenario ‘products’, are not narrowly economic in nature. Nonetheless many of their characteristics are influenced if not actually determined by practices originating in economic analyses. This is most evident simply in the use of economic output (Gross Domestic Product (GDP) or Gross World Product (GWP)) as the overwhelmingly dominant (usually, only) indicator of human welfare. And, importantly for our purposes here, the use of these scenarios in economic policy analyses (like the Stern Review, which used the A2 scenario explicitly in its modeling) means we can look at the pathway by which the treatment of income distribution in the scenarios is incorporated into, and influences, policy judgments.

It is widely recognized that the use of cost–benefit analysis (CBA) to evaluate ‘optimal’ climate policy is a controversial practice (see the IPCC’s own assessment reports, e.g. Toth and Mwandosya (2001); also Morgan et al. (1999)). Even its practitioners acknowledge both that other ethical concerns are relevant to climate policy, and that elements of CBA, such as the valuation of lives lost, are themselves inseparable from ethical judgments (see for example Stern (2006), chapter 2 and its technical annex 2A). Nonetheless the public debate over climate change takes place substantially in an economic cost–benefit framework, and prominent analysts such as Nordhaus (1994), Tol (1999) and Stern (2006) have been influential intellectually and politically.

Criticals of climate CBA have focused heavily but not exclusively on concerns about intergenerational equity, and particularly about the legitimacy of discounting future benefits and harms (Azar and Sterner 1996, Howarth and Monahan 1996, Spash 2007). While there are some who reject economic approaches to discounting the future on the basis of non-utilitarian ethical concerns (e.g., Sagoff 1988, Brown 1998) economists themselves (like Stern) argue that while some aspects of the practice may be ethically controversial, the broad method is necessary and unavoidable. Crucially, though I think this is not widely understood outside of the field, economists argue that equity considerations are in fact a central justification for discounting. While economists come down on different sides of whether its OK to discount the future just because it is the future (captured in the so-called ‘social rate of time preference’—see Arrow et al (1996) or Stern (2006), chapter 2), they agree that it is OK and in fact necessary to discount the future because it will be richer. As Beckerman and Hepburn (2007) put it, ‘most of the people alive today live lives that are, at best, precarious and, at worst, verging on the intolerable. It would be clearly inappropriate to ask those currently living in destitution to make sacrifices for a future that is likely to be richer than the present’. (For an interesting look at what happens if this condition fails to hold, at least in some regions, see Tol and Yohe (2007)).

However, the principle, and the math that is used to represent it, also imply that income for today’s rich adds less to the global welfare than the same income for today’s poor. This phenomenon—captured by the economic term ‘the declining marginal utility of income’ (or consumption)—is the justification for the practice of explicit ‘equity-weighting’, a method for taking account of intragenerational equity in economic analyses.

Equity-weighting in economics most generally means giving more or less numerical ‘weight’ to the welfare of some group (e.g., countries, people) in the calculation of an aggregate welfare measure. Indeed, discounting is really just equity-weighting across time, but since the term and concept of discounting are already widely known, the term ‘equity-weighting’ is typically used to mean giving differential weight to the welfare of persons or countries at different income levels at the same point in time.

4.1. The ‘utility’ equation

Economists typically use a standard, simple mathematical function to convert income or consumption by different agents into a quantitative measure of ‘utility’ or ‘welfare’:

\[ u = \frac{c^{1-\eta}}{1 - \eta} \]

where \( u \) is ‘utility’, \( c \) is ‘consumption’ and \( \eta \) (eta) is an ‘inequality aversion’ parameter. (For a discussion of this formula see Stern (2006) chapter 2A, or Arrow et al (1996);
for a flavor of the post-Stern discussion that has arisen, see Weitzman (2007), Yohe and Tol (2008), or Dietz et al. (2008). The default that is used in the most influential studies (e.g., those of Nordhaus and Stern) is to set the parameter $\eta = 1$ such that the equation reduces to $u = \log n(c)$. This is arguably quite steeply ‘progressive’ inasmuch as it implies that a ten dollar cost to a person earning (or consuming) 1000 dollars a year counts as much against total welfare as a ten-thousand dollar cost to a person earning (or consuming) one million dollars (I leave the proof of this as an exercise to the reader).

As noted in the Stern Review and various commentaries on it, the parameter $\eta$ (eta) has properties that lead it to be regarded simultaneously as an ‘inequality aversion’ parameter, as an ‘intertemporal substitution’ parameter, and as a ‘risk aversion’ parameter. Yet a variety of empirical evidence suggests that people think about the equity concerns associated with the three broad domains—distance (including nationality), time and risk—in very different ways, and some researchers have begun speculating about alternative ways of representing these concepts mathematically (Dietz et al. 2008).

Crucially, a consequence of using one parameter to address these three different ethical considerations is that, in a given model, a stronger aversion to inequality in the present (higher $\eta$) simultaneously leads to greater discounting of the future; as a consequence, in analyses like Stern’s, greater concern for the poor today leads to the acceptance greater ‘optimal’ climate change (Stern 2006, technical annex). This is not entirely absurd, since, as noted above, it might well be considered fair to protect today’s poor at the expense of the future not-so-poor. But again, the reasons for limiting the model in this fashion are less than compelling, and, as Dietz et al. (2008, p 14), note, ‘specifying a richer welfare economic model is likely to have a significant impact on results in the economics of climate change’.

Even with the conventional formulation, however, because of the nonlinear way in which welfare gains and losses are associated with income (consumption), anytime an average cost or benefit is being ‘divided’ across a population, the net ‘welfare’ calculated will depend on the resolution at which the population is modeled. That is, if you take 100 dollars from everyone in a country with a given per capita (average) income, you will get a different estimate of the total welfare loss every time you divide the country into two units with a higher and a lower average income.

That welfare estimates depend on the resolution of those estimates has been noted before (Tol 2001, Anthoff et al. 2009). And changing the resolution at which inequality is measured will have ambiguous effects on policy conclusions, particularly if economists continue to use a single function for both the declining utility of future impacts due to economic growth, and for the varying ‘equity weights’ given to richer and poorer persons at the same time. Anthoff et al. show that the ‘social cost of carbon’—an indicator that aggregates the harms from a unit of GHG emissions across all of time and space—can vary by more than a factor of two, just moving from regional (many country) scale to country scale. By extension, the most accurate calculation of welfare loss would require (using these assumptions) an exact measure of each individual’s income or consumption. The method I propose below models this approach to individual incomes, and indicative calculations suggest that the scale of the results is similarly significant.

A second consequence of this simple assumption about the relationship of consumption or income changes to welfare changes is that, for any given cost, the smallest calculated social welfare loss comes from distributing the cost from the top down, and for any given benefit, the greatest social welfare gain comes from distributing the benefits from the bottom up. Quite literally welfare is maximized if you start with the richest individual and decrease their income and consumption until they are tied for richest; then you tax the top two until it is a three-way tie, and so forth. Ditto for the benefits—give to the poorest till they are tied for poorest, etc. This is simply how the math works. Any other distribution—however justified—will, for a calculation at a single point in time, produce less total ‘welfare’.

Much could be said about this. On the one hand, the reasonableness of the broad principle (the declining marginal utility of income) is one justification for progressive taxation and thresholds of tax exemption. On the other hand, the fact that no economist is ever heard advocating for this kind of literal policy makes it clear that economists have a much more nuanced view of fairness than is reflected in their simple formula for converting consumption to ‘welfare’; they acknowledge the reality that transfers of income raise other considerations of equity beyond how much utility the associated consumption provides. Philosophically this is an acknowledgment that people (and countries, when modeled as people) are in fact not strictly utilitarians.

Based on these considerations, in the remainder of the paper I demonstrate a model that estimates the income distributions within countries, and that aggregates across countries on the basis of income level. I will use this model to show two things. First, I will show in some detail the differences in the way total ‘welfare’ and changes in welfare are measured in such a model as opposed to a model based on national per capita incomes, as well as the effects of changes in subnational income distributions over time. Second, I will show the consequences of such a model of subnational income distributions for estimates of an equity-based ‘capacity’ indicator that in turn can drive calculations of the distribution of climate-related obligations—so-called ‘burden sharing’. My basic point is simply that the implications of these examples are sufficiently important that future climate–economy scenarios need to take them into account, and that analyses—especially but not only optimizing calculations—which fail to account for subnational income distributions should be considered not robust to first-order concerns about equity.

5. Modeling subnational income distributions

5.1. The impact of disaggregation level on ‘utility’ and utility changes

In what follows, I use a simple formula that models a national income distribution as a lognormal distribution, using
the Gini coefficient (a widely used measure of income or consumption inequality) and per capita income as parameters (Kemp-Benedict 2001). This method dates to at least 1931 and continues to be used by researchers at the World Bank and elsewhere for poverty calculations (Lopez and Servén 2006). This formula produces a continuous distribution that can be used to calculate the number of persons above, below or between any arbitrary income thresholds. By using this formula for every country, one can estimate the global income distribution at a much finer level than is possible by using whole countries. Similarly, using assumptions about the relationship between (say) carbon emissions or energy consumption and income, one can generate subnational and global distributions for those indicators as well (Baer et al 2008; see also Chakravarty et al 2009).

The SRES scenario families provided per capita income data that was standardized at the level of four regions (various models used in particular scenarios had up to 13 regions). As has been noted (e.g., van Vuuren et al 2007), applying a regional average growth rate to the individual countries in a region produces some implausible results, thus the ‘downscaling’ of SRES income projections necessarily requires some subjective judgments. In this study I use national income and population estimates from the ‘downscaled’ data set of van Vuuren et al (2007), further adjusted from Market Exchange Rate estimates of GDP to Purchasing Power Parity equivalents. Because PPP conversion rates are highly correlated with per capita income, treating them as constant when per capita incomes are converging gives unrealistic results; I use a very simple formula in which the PPP conversion factor for each country converges linearly from the 2005 value to one when the country’s per capita income reaches the 2005 US per capita income (the standard unit for PPP conversions).

Using this model also requires a dataset for Gini coefficients. One publicly available data set (WIID 2008) includes Gini coefficients for at least 129 countries. For the purposes of a related project, we have extended this data set by internet research and educated guesses to cover 195 countries (Baer et al 2008). In each case the most recent and/or ‘best’ estimate is assumed to be applicable in 2005. In the calculations reflected here, I compare assumptions of constant Gini coefficient and a very stylized convergence formula; in spite of the broad correlation between income equality (as measured by Gini coefficients) and per capita income (the median Gini for Annex I (industrialized) countries, non-population weighted, is 0.31, versus 0.45 for the non-Annex I (developing) countries), empirical evidence of causal and even correlative regularities in national trends is weak (Chakravarty 2006). Thus there is no obvious ‘Business as Usual’ trend to use.

The tables below show the results of combining the standard utility transformation described above, using the typical case $\eta = 1$ and $u = \log n(c)$, with the lognormal model of subnational income distribution. The tables show what is typically hidden in cost–benefit analyses of climate change, which is the calculated ‘utility’ derived from the transformation of consumption (in this case, the log of income, rather than consumption).

First, table 1 shows for the year 2025, in the B1 scenario as I have converted it to PPP adjusted dollars (what I will call my ‘realization’ of the scenario), the global and average ‘utility’ and the equivalent global per capita income for three different ways of aggregating across the population. The first row aggregates at the global per capita income of $12938; total ‘utility’ is simply the projected global population (7.9 billion) multiplied by the average per capita utility, which is log n (12 938) or 9.47 (these units are sometimes called ‘utils’, but the term adds no additional meaning). Conceptually, this is the amount of ‘utility’ in a world of identical people, in which everyone in fact has the average income.

Second, the second row shows the result if global utility is aggregated on the basis of national per capita income: that is, the utility for each country is calculated by multiplying its population by its per capita utility, and the national totals are added to get the global total. The result is a substantially lower figure (about 4% lower), equivalent to an equal global distribution of only $8972. (Note that because of the nature of the log transformation, the 4% difference in ‘utility’ is equivalent to a much larger difference in per capita income.)

The third and fourth rows show the results of disaggregating by subnational income distribution. In theory, this model calculates the utility for each individual, based on their per capita income as estimated by the lognormal distribution and the parameters (per capita income, Gini coefficient) for the country they live in; in practice it is

| Method of aggregating welfare                          | Total ‘utility’ (billions) | Average (per capita) ‘utility’ | Equivalent per capita income ($PPP) |
|--------------------------------------------------------|----------------------------|--------------------------------|-----------------------------------|
| Aggregated by global per capita income                 | 74.7                       | 9.47                           | 12 938                            |
| Aggregated by national per capita income               | 71.6                       | 9.08                           | 8 792                             |
| Aggregated by national (lognormal) income distribution, current Gini | 68.5                       | 8.69                           | 5 933                             |
| Aggregated by national (lognormal) income distribution, convergent Gini | 69.4                       | 8.80                           | 6 656                             |
Table 2. Calculated ‘utility’ and equivalent per capita income and income losses based on hypothetical global costs of 1% of GWP in 2025 in the B1 scenario.

| Method of aggregating welfare | Total ‘utility’ (billions) | Average (per capita) ‘utility’ | Equivalent per capita income ($PPP) | Equivalent loss in per capita income ($PPP) |
|-------------------------------|-----------------------------|-------------------------------|-------------------------------------|--------------------------------------------|
| Aggregated by global per capita income | 74.6 | 9.46 | 12 808 | 129 |
| Aggregated by national per capita income | 71.5 | 9.06 | 8 604 | 188 |
| Aggregated by national (lognormal) income distribution, current Gini | 68.2 | 8.64 | 5 660 | 273 |
| Aggregated by national (lognormal) income distribution, convergent Gini | 69.2 | 8.77 | 6 421 | 235 |

Table 3. Calculated ‘utility’ and equivalent per capita income and income losses based on distribution of costs of 1% of GWP in proportion to income, or to income above a threshold (based on B1 scenario in 2025).

| Method of aggregating welfare | Total ‘utility’ (billions) | Average (per capita) ‘utility’ | Equivalent per capita income ($PPP) | Equivalent loss in per capita income ($PPP) |
|-------------------------------|-----------------------------|-------------------------------|-------------------------------------|--------------------------------------------|
| Aggregated by national (lognormal) income distribution, no threshold | 68.45 | 8.68 | 5874 | 59 |
| Aggregated by national (lognormal) income distribution, $7500 threshold | 68.49 | 8.68 | 5903 | 30 |
| Aggregated by national (lognormal) income distribution, $25 000 threshold | 68.51 | 8.69 | 5918 | 15 |

calculated from an algorithm that groups people into one of 715 ‘bins’ and multiplies the number in the bin by the average (log-transformed) income of the bin. The third row is based on the assumption that Gini coefficients remain the same as 2005; the fourth row is based on the assumption that they converge downward (equality increases) over time (Ginis over 0.30 converge towards 0.30 with a ‘half-life’ of twenty years; Ginis below 0.30 remain constant). The third row shows that with current levels of subnational inequality, the global income would be equivalent to only $5933 per capita (evenly distributed) in 2025; the fourth row says that with the modeled decrease in inequality, it would be equivalent to $6656.

If one assumes that the log-transform of income is a reasonable approximation of the declining marginal utility of income, then these results are perhaps interesting in their own right, as they show the scale of the loss of ‘utility’ from the unequal distribution of income. The point here, however, is that mainstream climate CBAs do in fact assume that the log-transform of income is an appropriate estimate of utility, and base their policy recommendations on calculations that make that assumption. And as suggested above and shown further in section 5.2, the recommendations are plainly sensitive to the level of disaggregation, as well as to the assumptions made about changing inequality. (Note however that we are showing only a single year snapshot, whereas climate CBAs integrate over the time dimension as well.)

Table 2 shows the change in utility from the ‘baseline’ shown in table 1 on the assumption that there is a 1% of GWP (about $1 trillion) ‘cost’ from climate change in 2025, in a world with B1’s international income distribution, calculated in different ways. The first row, like the first row in table 1, simply subtracts 1% ($129) from global per capita income; calculated average and total utility are, by definition, equivalent to a global per capita loss of that amount. The second row, like the second row in table 1, disaggregates to the national level; $129 is subtracted from the per capita income of each country, before converting to ‘utility’ and multiplying by population. The result is a loss in global and average utility equivalent to a $188 per capita loss in GWP. The third and fourth rows subtract $129 from each hypothetical individual based on the same lognormal model of income distribution (note however that we assume that per capita income never goes below $50); in this case the equivalent losses are $273 per capita (constant Gini) and $235 per capita (convergent Gini).

The importance of this result for cost–benefit analysis of climate change is two-fold. First, the estimated loss of utility and equivalent loss in GWP will vary greatly depending on whether the calculation is done on the basis of globally averaged, nationally averaged, or fully disaggregated (‘individual’) income estimates. Again, this is not an entirely new result, as it follows on the work of Anthoff et al on the difference between using national or regional per capita incomes in the calculation of the ‘social cost of carbon’. However, it shows that disaggregation below the national level can have an equally large or larger consequence in calculated utility losses. And furthermore, the assumptions that are made about how subnational income distributions change over time—a function of the storyline in a scenario exercise like the
Table 4. Results of calculation of 'capacity' (income above a threshold of $7500 per capita), modeled on an individual basis but aggregated at the global level. Based on realization of SRES A1B scenario as described above, constant Gini coefficients.

| Year | GWP ($Trillion, PPP adjusted) | Capacity as pct of GWP | Population over threshold (pct) | Average capacity | Pct of capacity in Annex I | Pct of population in Annex I |
|------|-------------------------------|------------------------|---------------------------------|------------------|---------------------------|----------------------------|
| 2000 | 40.5                          | 54.1                   | 20.7                            | 17.285           | 83.8                      | 20.4                       |
| 2010 | 60.5                          | 55.2                   | 27.9                            | 17.396           | 76.1                      | 18.9                       |
| 2020 | 92.9                          | 57.5                   | 43.1                            | 16.294           | 63.9                      | 17.7                       |
| 2030 | 141.2                         | 63.8                   | 63.8                            | 17.330           | 49.9                      | 17.0                       |
| 2040 | 201.9                         | 70.9                   | 80.5                            | 20.980           | 39.9                      | 16.5                       |
| 2050 | 267.3                         | 76.6                   | 90.2                            | 26.274           | 34.3                      | 16.2                       |

SRES—will also significantly affect the aggregate utility losses associated with a total level of global costs.

Finally, in table 3, I show another point that is fundamental to cost–benefit analysis, but is rarely made explicit, which is that the welfare changes associated with a policy-related cost are highly dependent on how the costs are assumed to be distributed. Table 3 shows the results of a calculation in which the same total cost of 1% of GWP in 2025 is allocated in proportion to income, rather than on an equal per capita basis—as if, for example, it were an income tax used to pay for mitigation. The first row simply subtracts 1% of income from everyone; the result is a loss in total and average welfare equivalent to a $59 reduction in global per capita income—much smaller than the $129 per capita figure which is the global average. Based on realization of SRES A1B scenario as described above, constant Gini coefficients.

Specifically, we define in the GDRs framework a ‘development threshold’, an income level below which persons are exempted from the financial burdens associated with the global public good of climate protection; although this is a normative judgment for which there can be no ‘correct’ value, elsewhere we argue that $7500 (PPP adjusted) is a reasonable figure (Baer et al 2008). Using the method described above (modeling subnational income distributions as lognormal), the table shows the global ‘capacity’ and the estimates for the industrialized and developing countries under my realization of the A1B scenario.

First, aggregating at the entire global level, table 4 shows GWP, the fraction of GWP that is counted as capacity—that is, income minus $7500 for those who are over the development threshold, and zero for those who are under the development threshold—as well as the percentage of the global population who are over the threshold, and the average amount by which their income exceeds that threshold. Note that even this globally aggregated calculation cannot be done correctly without subnational income distributions. The last two columns show the fraction of capacity that is in Annex I and the fraction of the global population that is in the Annex I countries.

These last columns are relevant to a critical policy question regarding the equitable allocation of climate-related burdens: what should be the appropriate division of obligations between Annex I and non-Annex I countries? This table shows that roughly three fourths of ‘capacity’ measured this way is held in the Annex I countries today versus about one half as soon as 2030, if incomes grow at the projected high levels in the A1B scenario; yet this fraction will still be much higher than the Annex I share of population. In this light, it is reasonable for non-Annex I countries to be asked to collectively accept a substantial share of global climate obligations, but individuals would on average expect to have much higher obligations in the richer countries. (We ignore for a moment additional considerations beyond a pure metric of capacity—such as the failure of Annex I nations to live up to their obligations under the UNFCCC—that are plausibly relevant to the allocation of obligations between the Annexes, at least in the short term—see Baer et al (2008).)

Table 5 presents the capacity calculation shown above, for the non-Annex I countries only, under two versions of the A1B
scenario with constant or convergent Gini coefficients. For each variant the table displays capacity as a per cent of GDP, the per cent of the population over the $7500 development threshold, and the ‘average capacity’ of the persons over the threshold. All of these are dependent on both the total GDP and the distribution of income.

Table 5 shows that in the more unequal (constant Gini) world, there are fewer people over the development threshold, but they have more capacity (income). In the context of this analysis, this shows that obligations would be different under a system like GDRs in scenarios with different subnational income distribution. In turn this suggests that under a system like GDRs in which national obligations were calculated on this basis, countries could literally reduce their international obligations by increasing the equality of their income distribution.

Quantitatively, using these assumptions, the reduction in ‘capacity’ from increasing equality is on the order of 5% in the coming decades, while the increase in the percentage living above the development threshold is on the order of 10–15%. Especially in a system like GDRs in which there is an exclusion of emissions from the ‘responsibility’ calculation that is proportional to the exclusion of income below the development threshold, this could lead to a significant variation in national obligations. Indeed, the aggregation of all non-Annex I countries together in table 5 conceals the fact that countries with currently higher Gini coefficients (greater inequality) that converge faster than average would show greater differences in their income distribution.

This example makes two main points. The first is that there is at least one kind of policy proposal for which the modeling of subnational income distribution is an essential component (GDRs is not actually the only such proposal—see Chakravarty et al. (2009)), which also uses modeled income distribution as correlate of the distribution of per capita emissions, on which their proposal is based). The second is that there are prima facie reasons to believe that the modeling of changing inequality over time will significantly affect the calculation of obligations in such models.

As I suggested at the very beginning, there are good reasons to think that impact, adaptation and valuation studies will also be significantly affected by projections of subnational income distributions. One might well imagine that in this context there were important other ‘equity concerns’ that might well be quantifiable, if one believes for example that ‘social capital’ acts to reduce vulnerability, and can be measured and modeled. On these grounds too, then, I believe there is plenty of reason to think that a more comprehensive approach to distribution within countries is appropriate in the next round of scenario development.

This in turn raises the question of what are plausible storylines in these terms, which returns us to what I refer to as ‘the contested storyline of the present’. Just as Castles and Henderson disputed whether international inequality is inequity, the same issues can be raised regarding inequality within countries. In the US, for instance, one perspective might be that the increasing inequality in the US is just a reflection of a pluralist political system responding to a globalizing world, and thus not in any way inequitable; another might see it as the consequence of a deliberate effort by a right-wing political coalition to undo the more egalitarian policies in place since the New Deal, and indeed plainly inequitable on that account.

My point again is two-fold. Whether a change in the trend of inequality in the US is considered likely or not is going to vary with one’s understanding of how it came to pass. Thus different views of the present will no doubt lead to a debate about what the range of plausible changes in inequality is ‘reasonable enough’ to use in subsequent studies, whether of mitigation or adaptation and vulnerability. Second, for those (like myself) who actually do consider the present level of inequality in the US and many other countries to be inequitable, what storylines we choose to develop and promote may in fact have something to do with what happens in the future; and in this light, developing scenarios that are normatively desirable becomes valuable even if they seem very unlikely today.

### 6. Conclusion

In this paper, I have focused on the claim that the inclusion of subnational income distribution in climate–economy scenarios is important for economic analysis of climate policies. To make this point, I showed how cost–benefit analysis calculates ‘utility’ based on the standard economic method for accounting for the declining marginal utility of income, which is regularly used in discounting the future but only rarely in ‘equity-weighting’ across nations. By extending the disaggregation of the utility calculation to the level of (modeled) individuals, I show that such calculations are at least as sensitive to a change from national level to individual level as from global level to national level. On this ground one can quite reasonably
claim that cost–benefit analyses that do not look at subnational income distribution—which is all of them so far—have not robustly established the plausible bounds on the costs of climate change or the benefits of climate policy.

However, while I argue that this failure to properly take account of the declining marginal utility of income calls into question the policy recommendations of the climate cost–benefit analyses of Stern, Nordhaus and others, this remains only one of many reasons to be skeptical of such analyses. Among other factors, the lack of robust methods for valuing unprecedented impacts like the melting of the Greenland Ice Sheet, the basic controversy over the valuation of human lives lost, and the lack of well-defined probability distributions for the most basic system parameters, all suggest that cost–benefit analysis of climate change and climate policy simply cannot produce quantitatively robust results (Spash 2007, Baer and Spash 2009).

Why then argue this point in particular? Two reasons are foremost. First, as a consequence of failing to account for the importance of subnational income distribution in calculating aggregate ‘utility’, standard climate CBAs may produce underestimates of climate damages, and thus recommend too little climate mitigation. Second, the inclusion of subnational income distribution makes it clear that the welfare impact of a given mitigation ‘burden’ can vary dramatically depending on how it is allocated. By building into policy models the ability to vary the distribution of costs for mitigation and adaptation, the sensitivity of ‘optimal’ policy to such choices can be explored. It would be fairly straightforward to show that the more ‘progressively’ the burden of any mitigation policy is distributed, the lower its global welfare impact, and the higher the level of mitigation that would be ‘optimal’ given estimated mitigation and adaptation benefits.

I conclude with a point that returns to my earlier claim that the critical divide in the political and scholarly worlds is among those who think the world is equitable as it is, and those who think that it is not. For the former, the economic analysis of climate change policy appears as a kind of appeal to authority, which can be used by status quo interests to justify policies that maintain the existing distribution of rights and power (Ravetz 1994, Baer and Spash 2009), and, in the case of climate change, substantially endanger planetary life support systems. The latter perspective suggests that cost–benefit analyses will continue to be produced and used even though their results are demonstrably not robust to either value controversies or scientific uncertainties. In this context, any ways in which the internal quality standards of economics can be used to show the bias of the results against the interests of the poor and the survival of the planet make potentially important contributions to the ongoing controversies about climate change and climate policy.

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10
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