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Jeroen C. J. M. van den Bergh & W. J. Wouter Botzen

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Global impact of a climate treaty if the Human Development Index replaces GDP as a welfare proxy

Jeroen C. J. M. van den Bergh[a,b,c,d] and W. J. Wouter Botzen[d,e]

[a]ICREA, Barcelona, Spain; [b]Institute of Environmental Science and Technology, Universitat Autònoma de Barcelona, Barcelona, Spain; [c]Faculty of Economics and Business Administration, VU University, Amsterdam, The Netherlands; [d]Institute for Environmental Studies, VU University, Amsterdam, The Netherlands; [e]Utrecht University School of Economics, Utrecht University, Utrecht, The Netherlands

ABSTRACT
This study explores the implications of shifting the narrative of climate policy evaluation from one of costs/benefits or economic growth to a message of improving social welfare. Focusing on the costs of mitigation and the associated impacts on gross domestic product (GDP) may translate into a widespread concern that a climate agreement will be very costly. This article considers the well-known Human Development Index (HDI) as an alternative criterion for judging the welfare effects of climate policy. We estimate what the maximum possible annual average increase in HDI welfare per tons of CO_2 would be within the carbon budget associated with limiting warming to 2°C over the period 2015–2050. Emission pathways are determined by a policy that allows the HDI of poor countries and their emissions to increase under a business-as-usual development path, while countries with a high HDI value (>0.8) have to restrain their emissions to ensure that the global temperature rise does not exceed 2°C. For comparison, the well-known multi-regional RICE model is used to assess GDP growth under the same climate change policy goals.

Policy relevance
This is the first study that shifts the narrative of climate policy evaluation from one of GDP growth to a message of improving social welfare, as captured by the HDI. This could make it easier for political leaders and climate negotiators to publicly commit themselves to ambitious carbon emission reduction goals, such as limiting global warming to 2°C, as in the (non-binding) agreement made at COP 21 in Paris in 2015. We find that if impacts are framed in terms of growth in HDI per t CO_2 emission per capita instead of in GDP, the HDI of poor countries and their emissions are allowed to increase under a business-as-usual development path, whereas countries with a high HDI (>0.8) must control emissions so that global temperature rise remains within 2°C. Importantly, a climate agreement is more attractive for rich countries under the HDI than the GDP frame. This is good news, as these countries have to make the major contribution to emissions reductions.

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1. Introduction

The implications of changing the framing of climate policy from a perspective of economic growth impacts to a message of improving social welfare are explored here. This involves quantifying alternative metrics for better approximating welfare effects. Such an approach might make it easier for political leaders and climate

CONTACT W. J. Wouter Botzen wouter.botzen@vu.nl
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negotiators to publicly commit themselves to ambitious carbon emission reduction goals (van den Bergh, 2010). Many of the negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) before Paris were arguably unsuccessful partly because of a focus on the costs of mitigation and the associated impacts on gross domestic product (GDP) (European Parliamentary Research Service, 2015). This translates into widespread concern that a climate agreement will be very costly, although some debate this outcome. Even the recent non-binding agreement reached at the Conference of the Parties (COP) to the UNFCCC in Paris in 2015 involves national pledges (i.e. Intended Nationally Determined Contributions) that are far from sufficient to limit global warming to less than 2 or 1.5°C, but instead are expected to lead to median warming of 2.7°C, with an uncertainty range of 2.2–3.4°C (http://climateactiontracker.org), based on current pledges – which may change over time. There is thus a need for further analysis of climate change and policy using better indicators of social welfare. We consider the well-known HDI as an alternative criterion for judging the welfare effects of climate policy. It captures other elements of social welfare in addition to GDP by including life expectancy and education as measures of the standard of living (United Nations Development Programme [UNDP], 2014). Moreover, the HDI is better suited to capture important dimensions of welfare in developing countries, including very poor nations (UNDP, 2014).

In climate change debate and policy analysis, health is a somewhat underestimated issue. More attention to it might broaden the support for stringent, safe climate policy and an associated climate agreement, as it did for the Montreal Protocol on phasing-out ozone-depleting substances. That health impacts from climate change can be substantial is clear e.g. from the predicted increase in vector-borne diseases that may occur in developing countries due to climate change (Dasgupta, 2016; Sutherst, 2004). Brooks, Adger, and Kelly (2005) estimate how deaths from climate-related disasters are influenced by a broad range of indicators of the vulnerability of a country to natural hazards. They find that among other factors, life expectancy (related to health) and education – which are both part of the HDI – significantly correlate with deaths due to climate-related disasters, while GDP has an insignificant correlation. In particular, countries that score low on components of the HDI, such as sub-Saharan Africa, are particularly vulnerable to climate-related disasters. The direct connection of climate change and policy with education is less clear. Education may help people to be better prepared for, and thus adapt to, climate change (Anderson, 2012). It has been found that the correlations between CO_2 emissions and education and life expectancy are weaker than with GDP (Costa, Rybski, & Kropp, 2011). This suggests that shifting (other) GDP activities to education and health care would limit GHG emissions.

GDP is the monetary, market value of all final goods and services produced over a period of a year. It is available in a standardized form for most countries over a long period of time, which contributes to its popularity in politics and the media, as well as its widespread use in economic studies. But it has serious shortcomings as an indicator of social welfare, development or progress that are well documented (e.g. Arrow et al., 1995; van den Bergh, 2009; Costanza et al., 2014; Daly & Cobb, 1989; Mishan, 1967; Victor, 2010). Among others issues, GDP does not capture the saturation of individual welfare income or consumption, relative welfare effects (status), inequity, the shifting of informal activities to formal markets (typical of development processes in poorer countries), the depletion of natural resources, the impairment of human health due to problems such as pollution and the degradation of the environment.

Most economic studies on climate policy conceptualize the problem as a trade-off between the benefits of a policy and its costs[1] measured by the reduced GDP (Hope, 2011; Nordhaus, 2008; Tol, 2009). But if the latter is not a good gauge of changes in social welfare, as is notably the case for the richer countries with incomes above the threshold where income barely contributes to higher welfare (related to happiness), then the real welfare costs of climate policy are likely to be overestimated.

Here we consider the HDI as an alternative to GDP for various reasons. It is a better representation of social welfare and plays an important role in (inter)national policies aimed at development and poverty reduction.[2] Unmitigated climate change and climate policy affect a country's HDI in complex ways. For example, it has been suggested that climate change impacts, such as an increase in the frequency and severity of natural disasters, can limit or reverse improvements in the HDI over time, especially for vulnerable poor countries (Akanbi, Adagunodo, & Satope, 2014; UNDP, 2011, 2014), but improving the HDI can reduce vulnerability to climate impacts (Brooks et al., 2005). In addition, the HDI can serve as an indicator of a country's exposure to

Table 1. HDI by regions and groups.

Human development group or region	HDI value 2010	HDI value 2013
Very high human development	0.885	0.890
High human development	0.723	0.735
Medium human development	0.601	0.614
Low human development	0.479	0.493
Arab States	0.675	0.682
East Asia and the Pacific	0.688	0.703
Europe and Central Asia	0.726	0.738
Latin America and the Caribbean	0.734	0.740
South Asia	0.573	0.588
Sub-Saharan Africa	0.468	0.502
World	0.693	0.702

Source: UNDP (2014).

climate-related extremes in the sense that countries with a medium HDI experience the largest climate-related disaster impacts, whereas countries with a high HDI suffer to a much lower degree (Patt et al., 2010).

Empirical information on the current HDI levels of countries is summarized in Table 1. Rich countries do not differ much in their HDI values (0.87–0.94). Low-, medium- and high-HDI countries show a wider range: the lowest-ranked countries, which are in Sub-Saharan Africa, have an HDI value of 0.5, medium-ranked countries about 0.61 and high-ranked nations about 0.73 (UNDP, 2014). In addition, the HDI tends to increase for most countries over time: by very little for rich countries, but by a much larger amount for poorer countries.

The new approach presented in this study aims to quantify how much welfare growth is possible under a GHG emissions pathway that limits the global average temperature rise to 2°C. We will compare this with a policy that maximizes world GDP. One particular concept and indicator that will be used is the welfare per unit of carbon emissions, to capture the welfare productivity of carbon emissions.[3] For the HDI analysis, we build upon the empirical approach used by Costa et al. (2011), who examine the implications of climate policy that reduces emissions in line with a target of limiting global temperature increase to 2°C. The proposed climate policy framework allows developing countries to follow the development path taken by developed countries, while developed countries (with a HDI value >0.8) reduce their per capita emissions on the basis of a reduction rate that increases proportionally with HDI[4] and keeps total emissions within the allowed limit of 2°C temperature rise with a 75% probability (Meinshausen et al., 2009). We apply this framework to reframe climate policy impacts in terms of HDI changes, which allows us to determine the growth rate of HDI per tCO_2 emitted per capita when climate policy limits temperature rise to 2°C.

2. Methods

2.1. HDI calculations

We use data from Costa et al. (2011) who derive CO_2 emission pathways that are compatible with a climate policy that limits the global temperature rise to 2°C and maximizes the HDI. The following three steps are taken to calculate the HDI changes under allowable CO_2 emissions that underlie our climate policy frames.

2.1.1. Step 1

For each country the yearly HDI level between 2015 and 2050 is calculated on the basis of a development-as-usual (DAU) path (Costa et al., 2011). On average the total HDI increase in this period is 14.59% and the yearly average HDI growth rate is 0.38%.

2.1.2. Step 2

The annual CO_2 emissions per capita from burning fossil fuels that Costa et al. (2011) report for five-year intervals (under a climate policy that limits warming up to 2°C) are used to calculate yearly per capita emission for countries between 2015 and 2050, based on a linear extrapolation of emissions. Costa et al. (2011) derived these emissions as follows. A DAU HDI path is generated for each country to 2050, as well as the corresponding per capita emissions of CO_2 from burning fossils resulting from emissions' positive correlation with the income component of HDI. This results in global cumulative CO_2 emissions for the period 2000–2050. Next, the DAU scenario is used as a baseline for designing emission pathways that maximize the HDI and constrain the temperature rise to 2°C. Emission budgets are estimated for groups of countries defined as developing (HDI<0.8) or developed (HDI>0.8) in order to identify emissions as being necessary for development or as occurring after development (Supplementary Table 1). The HDI framework is then used to allocate allowed CO_2 emissions that the temperature rise is limited to 2°C (Supplementary Tables 1 and 2).[5]

2.1.3. Step 3

The generated information about the yearly HDI from step 1 and about emissions from step 2 are combined to calculate a time series (2015–2050) of yearly HDI per tCO_2 emitted per capita for each country. The resulting variable can increase or decline over time: the HDI of a country increases, while per capita emissions can increase as well if the country is still in a phase of development, or emissions can decline if it has reached the threshold HDI. Finally, the annual average growth in the HDI per tCO_2 emitted per capita is derived for each country to create climate policy targets for the various regions, as well as a world average. This average yearly growth of HDI per tCO_2 per capita indicator over the 35-year period is calculated using:

$$\left(\left(\frac{\mathrm{HDI}_{i,\,t=2050}}{C_{i,t=2050}} \Big/ \frac{\mathrm{HDI}_{i,t=2015}}{C_{i,t=2015}}\right)^{\left(\frac{1}{35}\right)} - 1\right) \times 100,$$

where $\mathrm{HDI}_{i,t}$ is the HDI level of country i at year t and $C_{i,t}$ is the emission of CO_2 per capita of country i at year t.

2.2. GDP calculations

We obtain results for the GDP frame using the regional integrated model of climate and the economy (RICE) model developed by Nordhaus (2010). This is a multi-regional integrated assessment model (IAM) that divides the world into 12 regions. We calculate RICE results for a climate policy scenario that limits global warming to 2°C. This involves three steps. First, we calculate for each RICE region the annual GDP between 2015 and 2050. For this we use the RICE results for the variable 'Net National Income', which is closely related to GDP. Second, the economically optimal annual CO_2 emissions[6] of RICE per decade under the climate policy that limits warming up to 2°C are used to calculate annual per capita emission per country between 2015 and 2050, based on a linear extrapolation of the total emissions and dividing these by population to obtain per capita emissions. RICE emissions include all GHG emissions[7] and are reported in gigatons of carbon, which is converted here to tCO_2. This results in worldwide average per capita CO_2 emissions over this period of about 3.7 t yr^{-1}. Third, the information generated about GDP from step 1 and about emissions from step 2 are combined to calculate a time series (2015–2050) of annual feasible GDP per tCO_2 emitted per capita for each region. This is calculated using the formula GDP_t/per capita CO_2 emissions$_t$. A per capita representation is used to correct this welfare indicator for population size. This variable increases over time because of both growth in GDP and the required decline in per capita emission to limit temperature rise to 2°C. Finally, the annual average growth in the GDP per tCO_2 emitted per capita is calculated for each RICE region to create reframed climate policy targets for these regions, from which a world average can be derived. This average annual growth (in %) of GDP per tCO_2 per capita indicator over the 35 year period is determined using the formula:

$$\left(\left(\frac{\mathrm{GDP}_{i,\,t=2050}}{C_{i,t=2050}} \Big/ \frac{\mathrm{GDP}_{i,t=2015}}{C_{i,t=2015}}\right)^{\left(\frac{1}{35}\right)} - 1\right) \times 100,$$

where $\mathrm{GDP}_{i,t}$ is the GDP of country i at year t. This GDP frame represents the average annual feasible growth in GDP per tCO_2 per capita between 2015 and 2050 that can be obtained under the proposed climate policy to keep global warming below 2°C.

3. Results

3.1. HDI calculations

The results take the form of annual average growth in the HDI per tCO_2 emitted per capita for each country to create reframed climate policy targets per region, and can be aggregated into a world average, which equals 7.37% between 2015 and 2050.

Table 2 (left column) provides illustrative examples of how these results differ by country. The mean value of 7.37% is influenced by several relatively high values, as the median of 5.66% indicates. These growth rates are the combined result of a generally modest increase in the numerator of this indicator (HDI) and a decline in the denominator for high-HDI countries (i.e. a decline in the CO_2 emitted per capita) such as the US; or an increase in the denominator for low-HDI countries (CO_2 emitted per capita to allow for business as usual development) such as Tanzania. Note that emissions are allowed to increase in low-HDI countries as this is compatible with maximizing the HDI as proposed by Costa et al. (2011). If the effect of increasing emissions dominates the increase in HDI growth then the growth of this indicator is negative, as is the case for Tanzania, and to a lesser degree, India. It could be said that greater emissions are required to reach an improved HDI value.

These HDI-based results indicate that there is a dividing line between rich and poor countries. To further illustrate this, the highest scores for the growth in HDI per tCO_2 emitted per capita between 2015 and 2050 are reached for Luxemburg, Norway, Australia and Ireland (all more than 22%), while Chad and Benin have the lowest values (−5.79% and −3.44%, respectively). In addition, other countries with a value of 20% or higher are all rich countries (with a high HDI value): Canada, Spain, New Zealand, France, Singapore, Finland, the US, Sweden, Austria, Belgium, the Republic of Korea, Italy, Netherlands, Iceland, South Africa and the UK. On the other hand, countries with a value below −1% are mainly poor countries with a low HDI value: Ethiopia, Yemen, Pakistan, Bangladesh, Benin, Uganda, Lao People's Democratic Republic, Chad, Nepal, Senegal, Myanmar, Tanzania, Congo and Namibia. These findings indicate that the feasible HDI per tCO_2 emitted per capita can differ considerably between countries.

3.2. GDP calculations

Here we present the results of applying the RICE model (Nordhaus, 2010) to frame the results of climate policy in terms of GDP increases, notably to arrive at a feasible maximal growth rate of GDP per tCO_2 emitted per capita (Methods). The RICE model estimates emission pathways that maximize world GDP. The calculations are presented as the annual average growth in the GDP per tCO_2 emitted for each RICE region between 2015 and 2050 that can be obtained under the proposed climate policy to keep global warming below 2°C. Taking the average of the regional-level results gives a value of 4.62%. Table 2 (right column) illustrates how results differ between countries and regions.

Table 2. Country examples of the feasible growth rate of the HDI (left column) and GDP (right column) per tCO_2 emitted per capita under a proposed climate policy to limit global warming to 2°C.

Region or country	HDI	GDP
World/average	7.37%	4.62%
US	20.45%	4.40%
China	10.03%	5.19%
India	−0.95%	4.42%
Russia	1.27%	4.93%
Africa	n.a.	6.84%
Tanzania	−1.93%	n.a.

Notes: While the GDP results are shown for the African region (which is one of the RICE regions), such regional results are not available for our country level HDI analysis. Instead we provide the results of Tanzania as an illustrative example for this region; n.a.: not applicable.

All of the RICE regions experience positive growth in GDP per tCO_2 emitted per capita between 2015 and 2050. This is the outcome of both an increase in the numerator of this indicator (GDP) and a decline in its denominator (CO_2 emitted per capita). Emissions decline in all regions because this is compatible with maximizing world GDP under the 2°C temperature limit. These results show that the feasible GDP per tCO_2 emitted per capita can be quite similar between countries that have very different economies and income levels (like the US, China and Russia). The result for the African region can be understood as there being still many relatively low-carbon opportunities here for GDP growth.

3.3. Comparison

Differences between the GDP and HDI results in Table 2 are due to the emission pathways used for the GDP and HDI frames being based on distinct objectives, namely climate policy maximizing GDP and HDI, respectively. Figures 1 and 2 respectively show the HDI and GDP per tCO_2 emitted per capita between 2015–2050 under the 2°C temperature limit. The vertical axes are on a logarithmic scale for the purpose of readability.

It can be noticed from Table 2 that for developing countries the rate of growth in GDP per tCO_2 emitted per capita is in general higher than that for the HDI per tCO_2 emitted per capita. The latter does not take high values or can even be negative, as in the case of Tanzania, due to higher CO_2 emissions in these countries to lift them out of poverty. This is consistent with the policy objective proposed by Costa et al. (2011), namely to allow these countries to continue to emit to maximize their HDI. Figure 1 shows that the HDI per tCO_2 emitted per capita declines continuously over time. One might consider such countries as having had a low historical capacity to transform emissions to HDI. Welfare increases from CO_2 emissions in GDP terms in poor countries are

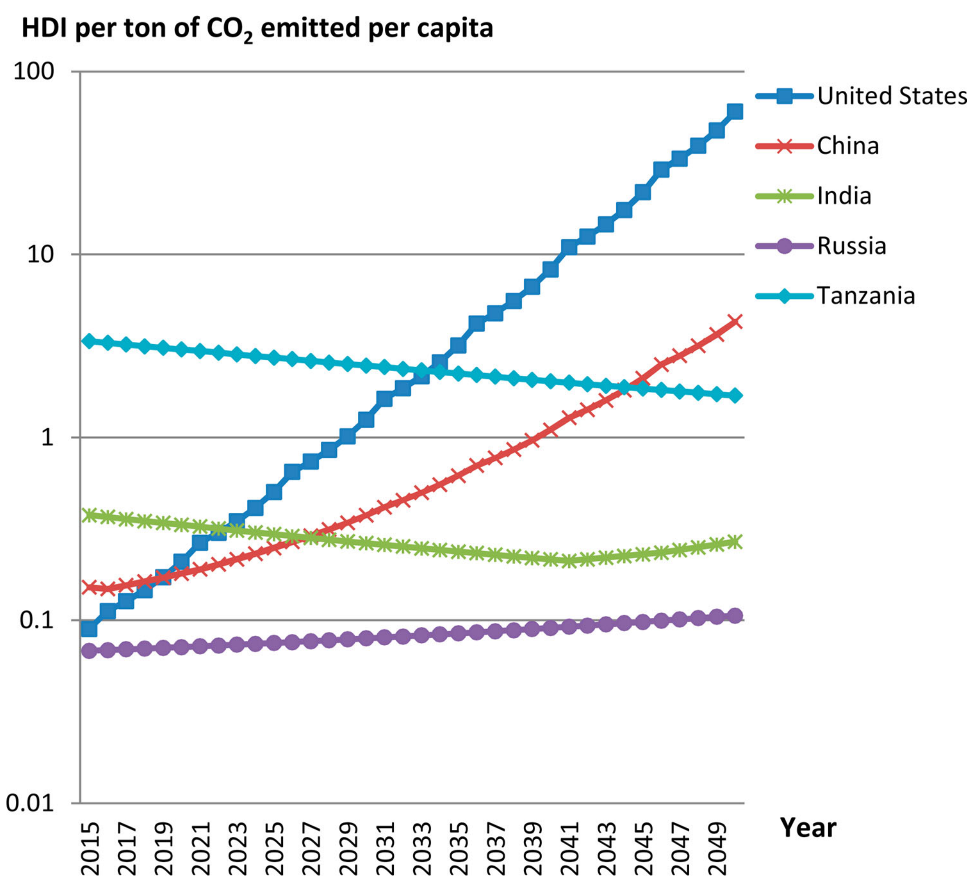

Figure 1. Time series of HDI per tCO_2 emitted per capita between 2015–2050 under a proposed climate policy to limit global warming to 2°C.

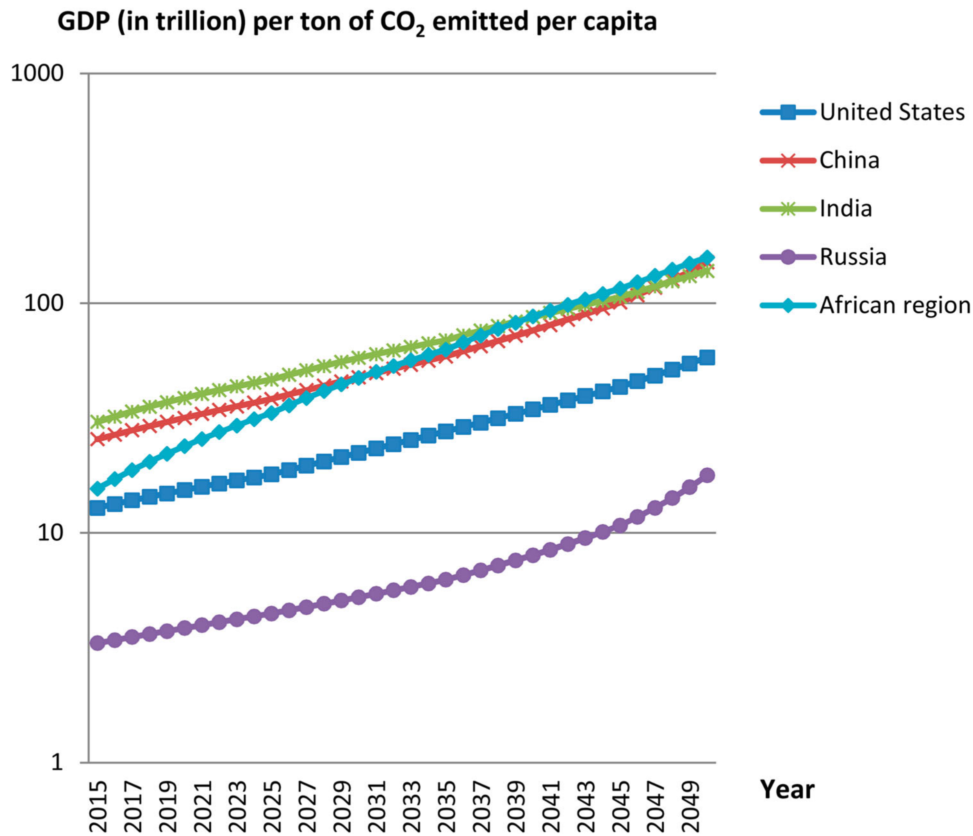

Figure 2. Time series of GDP (in US$ trillion) per t CO_2 emitted per capita between 2015–2050 under a proposed climate policy to limit global warming to 2°C.

overestimated if the correct objective is HDI growth. It is therefore questionable to use changes in the GDP as a guide for climate negotiations.

Considering specific countries, we find that the growth in HDI per tCO_2 per capita for Russia is slightly positive (reflected in the trend in Figure 1), which is the result of a small increase in the HDI level from 0.81 to 0.82 combined with declining emissions. On the other hand, for rich countries (like the US, which is a region in RICE) the findings are reverse – i.e. the rate of growth in the HDI per tCO_2 per capita emission for such countries is high compared with the similar rate of growth in GDP. This is reflected in the stronger HDI per CO_2 emissions trend in Figure 1 for the US than the GDP per CO_2 emissions in Figure 2. This means that a climate agreement will appear more attractive for such countries if it is framed in terms of growth in HDI per capita CO_2 emission. The results for rich countries are driven by the large emission reductions that are needed in these countries to stimulate HDI growth worldwide – which also applies to the GDP results, albeit to a smaller extent. This outcome holds for the world as a whole, as the average is dominated by that of the rich countries.

4. Discussion and conclusions

This study shows how a reframing of climate policy from GDP to welfare terms can be quantitatively tested, as illustrated by the HDI. The HDI analysis indicates that a 2°C limit to the global temperature rise offers opportunities and space for welfare growth in poor countries. In particular, 61 countries are lifted out of poverty by 2050 (HDI≥0.8) (Costa et al., 2011). At that point they will have to cut emissions. Of course the exact value of the adopted threshold of welfare is open to debate, but the value of 0.8 seems to be a reasonable reference value (Costa et al., 2011). Moreover, the RICE model results show that under a 2°C temperature rise limit, welfare growth for poor countries (like the African region) can also be obtained in terms of the more narrow per-capita GDP metric, even though the cost–benefit analysis of RICE shows that such a stringent climate policy is not optimal in GDP terms (Nordaus, 2010).

In summary, both HDI and GDP indicators show that development is compatible with the 2°C target. For poor countries, one advantage of evaluating climate policy using the HDI metric is that maximizing the HDI implies that they have to cut emissions later and, thereby benefit from being lifted out of poverty. An advantage for richer countries, like the US, who traditionally have been reluctant to implement stringent climate policies is that the HDI welfare growth in terms of per capita CO_2 is high relative to that for GDP.

Our analysis suggests that all countries – both low- and high-HDI – have to work towards low-carbon development while countries with an HDI value above 0.8 would need to provide the means of implementation or capacity-building for the low-HDI countries, e.g. through technology transfer and finance. On top of this, high-HDI countries should move as quickly as is feasible in the direction of low ('zero')-carbon intensity.

To improve this study, it would be helpful to have an adjusted HDI that also covers income inequality within countries, as this is likely to be strongly affected by climate change as well as climate policy. In performing this analysis, we were limited by the fact that the RICE model produces estimates for a limited number of (rather homogeneous) multi-country regions instead of for all of the individual countries. In addition, while the RICE model is based on theoretical, stylized pathways of GDP growth, the approach in Costa et al. (2011) is simpler and more empirical in nature. A more detailed and consistent comparison at the country level would require a similar but more disaggregated model.

It will not be easy to convince economists, policy makers and politicians – who habitually use GDP information – to replace this with an alternative that serves as a better proxy of welfare, whether the HDI or another measure. The fierce debate following The Stern Review (Stern, 2007), particularly with regards to discounting practices (Nordhaus, 2007; Stern, 2008, 2013; Tol & Yohe, 2007), indicates that one can expect strong resistance to efforts to change evaluation procedures and performance indicators. Likewise, moving away from monetary indicators like GDP (per capita) in climate impact and policy analysis can be expected to meet with opposition. But perhaps climate change can act as the critical driver to let go of the current GDP growth paradigm. This paradigm is widely regarded as the most significant environmental challenge to continued economic growth, but the debate on growth versus climate is also likely to intensify in coming years as the remaining carbon budget associated with the 2°C goal will rapidly decline.

One way forwards may be to evaluate climate policy using a broad set of indicators, including the HDI, to provide additional relevant information about welfare implications. A credible alternative for GDP may facilitate a transition away from the GDP growth focus. However, although the HDI is better than GDP in this context, it is not a perfect welfare proxy either (Hicks, 1997; Neumayer, 2001; Noorbakhsh, 1998; Sagar & Najam, 1998). One might thus want to use a more ideal welfare index (Botzen & van den Bergh, 2014). However, there are no consistent country data available for any alternative. For the foreseeable future, the HDI is as good as it gets.

Notes

1. For a recent review of the cost of climate change, see van den Bergh and Botzen (2015).
2. An additional advantage of this choice over other alternatives to GDP is that annual country-level data is available since 1990. It should be noted that the way the HDI is computed has slightly changed from 2010 onwards (UNDP, 2010).
3. A related concept is 'GDP carbon productivity', which means the amount of GDP produced per unit of carbon dioxide equivalent (CO_2e) emissions (McKinsey, 2008). Increasing this productivity is considered as the strategy to match economic growth and climate change goals.
4. As explained in Costa et al. (2011) a country's *i* per capita emissions *e* at year *t* are expressed as $(1-r_{i,t})e_{i,t}$ where the reduction rate $r_{i,t} = f(d_{i,t} - d^*)$ for $d_{i,t} > d^*$ of which $d_{i,t}$ is the HDI level at time *t*, d^* is the development threshold of 0.8 and *f* is the proportionality constant (set at 3.3).
5. This approach focuses on estimating emissions where they occur and therefore does not make adjustments for the emissions embodied in trade, such as the differences between where emissions are produced and the resulting goods are consumed.
6. Figure 1 in Nordhaus (2010) shows the RICE emission pathway that limits warming to 2°C, which is broadly similar to the RCP2.6 scenario of the Intergovernmental Panel on Climate Change.
7. Nevertheless, CO_2 makes up the majority of these emissions (Nordhaus, 2010).

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