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The Social Shortfall and Ecological Overshoot of Nations

Andrew L. Fanning, Daniel W. O'Neill, Jason Hickel, and Nicolas Roux

SUPPLEMENTARY INFORMATION

1. Downscaling Planetary Boundaries

Following O'Neill et al.[1] and Hickel[2], we apply equality-based shares of each planetary boundary throughout our analysis, which spans the 1992–2050 period. In order to downscale planetary boundary control variables to annual flows of per capita equivalents across countries, changes in population also need to be taken into account. We used data from the medium fertility variant of the United Nations Population Division's *World Population Prospects*[3] for historical estimates and forward-looking projections. Only countries with populations greater than 1 million people were included in our analysis. The following sub-sections provide details on each biophysical indicator used in our analysis.

1.1 Climate Change

The planetary boundary for climate change is generally expressed as a maximum concentration of CO_2 in the atmosphere of 350 ppm[4], which was crossed in 1988. Atmospheric CO_2 concentrations currently exceed 410 ppm[5]. Following Hickel[2], we calculated the total CO_2 emitted from 1850 to 1988 (770 Gt CO_2), before the 350 ppm boundary was crossed. This "safe" carbon budget was distributed across countries according to each country's population as a share of the global population, with populations averaged from 1850 to 2015, or

$$Fair\ share_n = 770 * \frac{Average\ population_{n,t=[1850:2015]}}{Global\ average\ population_{t=[1850:2015]}} \tag{1}$$

To estimate national performance in relation to these fair shares, country-level CO_2 emissions data were obtained from two sources. Consumption-based CO_2 emissions data that account for upstream emissions embodied in imports and exports from energy production (excluding biomass burning) and cement production were obtained from the Eora MRIO database[6,7] over the 1970–2015 period. For the earlier 1850–1969 period, consumption-based data were not available, so we followed Hickel's[2] approach and obtained a territorial measure from the PRIMAP-Hist dataset (v2.1)[8]. Population data from 1850 to 1969 were obtained from Gapminder[9], based on Maddison[10], and from the World Bank's *World Development Indicators* (WDI)[11] over the 1970–2015 period.

For each country, we calculated cumulative historical CO_2 emissions from 1850 to 2015 and projected business-as-usual trends out to 2050 (with 66% prediction intervals) using the dynamic statistical forecasting approach described in the Methods of the main text. We compared these country-level cumulative CO_2 emissions to national fair shares (Eq. 1) on a yearly basis. Overall, these methods and data sources for CO_2 emissions are directly comparable to Hickel's[2] approach.

1.2 Biogeochemical Flows

The planetary boundaries framework provides two sub-boundaries for biogeochemical flows, one for the nitrogen cycle and the other for the phosphorus cycle. The planetary boundary for nitrogen is 62 Tg N y^{-1} from industrial and intentional biological fixation[4], which was crossed in the early 1970s, and current global nitrogen fixation is approximately 150 Tg N y^{-1}.[12] We divided the planetary boundary for nitrogen by world population for each year in our analysis.

As far as we are aware, reliable time-series nitrogen footprint data do not exist for a large number of countries. The Eora MRIO database[6,7] contains a time-series of nitrogen footprint data over the 1970–2015 period derived from Oita et al.'s high-quality global analysis of nitrogen embedded in international trade[13], but the underlying nitrogen fertilizer data are only valid for the year 2010. The other years are simply re-allocations of the 2010 values based on year-on-year changes in trade flows mapped to the underlying MRIO structure.

In the absence of a reliable nitrogen footprint time-series for a large number of countries, we generated a proxy series in three steps. First, we obtained national nitrogen fertilizer data from Bouwman et al.[12], who provide high-quality territorial-based data over the 1970–2010 period, but these data do not account for the trade of final agricultural goods to other countries. Second, we calculated the ratio between Eora's consumption-based and territorial-based nitrogen time series (based on Oita et al.'s[13] allocation of national nitrogen use across industry sectors) for each country and year, in order to reveal the year-on-year changes in the underlying MRIO trade structure. Third, we multiplied these country- and year-specific footprint/territorial ratios by Bouwman et al.'s territorial nitrogen data to generate a proxy nitrogen footprint time-series indicator:

$$\widehat{Footprint}_{n,t} = \left(\frac{Eora\ Footprint_{n,t}}{Eora\ Territorial_{n,t}}\right) * Territorial_{n,t} \tag{2}$$

where $\widehat{Footprint}_{n,t}$ represents our proxy estimate for country n in year t of the consumption-based allocation of nitrogen fixation and fertilizer/manure applied to cropland. For each country, we calculated these proxy estimates over the 1992–2010 period and projected business-as-usual trends out to 2050 (with 66% prediction intervals) using the dynamic statistical forecasting approach described in the Methods of the main text. Given that the most recent date in this time series is 2010 (compared to 2015 for the other biophysical indicators), we present median forecasts over the 2011–2015 period to simplify the multi-indicator presentation of our results in the Main text. We compared these country-level nitrogen estimates to per capita shares on a yearly basis.

The planetary boundary for phosphorus is 6.2 Tg P y^{-1} mined and applied to erodible (agricultural) soils[4], which was crossed before 1970, and current global phosphorus fertilizer use is more than 14 Tg P y^{-1}.[12] We divided the planetary boundary for phosphorus by world population for each year in our analysis. Similar to nitrogen, we estimated proxy phosphorus footprints by combining territorial phosphorus fertilizer data from Bouwman et al.[12] with country- and year-specific ratios from the Eora MRIO global database derived from Oita et al.[13] (Eq. 6). This approach assumes that national phosphorus fertilizer use can be mapped across industrial sectors in the same way as nitrogen.

1.3 Land-System Change

The planetary boundary for land-system change is defined in terms of the amount of forest cover remaining (depending on forest biome), and it is equivalent to maintaining a minimum of 75% of global original forest cover (or approximately 48 million km^2 of ice-free land on Earth)[4], which was crossed before 1990[14]. Although in principle it would be possible to estimate a per capita boundary associated with global forest cover, and a comparable national indicator, the area of forested land associated with the consumption of goods and services is a crude (and difficult to measure) indicator.

Instead, we follow O'Neill et al.'s[1] approach and use a more nuanced indicator, namely "human appropriation of net primary production" (HANPP), which has been proposed as an alternative planetary boundary that integrates four of the current boundaries[15]. Net Primary Production (NPP) is the amount of biomass (expressed as carbon, dry matter, or energy) produced by primary producers (e.g. plants) through photosynthesis. Humans are appropriating NPP by converting land (e.g. from forest to grazing land or cropland), and by harvesting biomass through agriculture and forestry (including biomass that is killed during harvest but not used). By appropriating NPP, humans are reducing the carbon intake of primary producers, reducing energy available to other species (affecting biodiversity)[16–18], changing evapotranspiration and the water cycle[19], and enhancing wind erosion[20]. HANPP thus reflects both the land-system change and biosphere integrity boundaries, in particular, but is also linked to freshwater use and biogeochemical cycles to some degree[15]. HANPP includes not only the pressure humans put on forests, but also on other ecosystems, such as grasslands and savannahs.

As a planetary boundary for HANPP, we follow O'Neill et al's[1] method, which is based on an estimate that only 5 Gt C y^{-1} of potential NPP remained available for appropriation by humans in 2007[15]. We obtained national HANPP data that measure the consumption-based allocation of HANPP to final biomass products from agriculture and forestry, where trade is accounted for using physical bilateral trade matrices, also called *embodied* human appropriation of net primary productivity (eHANPP). Agricultural eHANPP data were obtained from Roux et al.[21] for the 1986–2011 period, and forestry eHANPP data for the 1997–2016 period were calculated based on data from analyses of trade in global forest products[22–25]. We created a 1992–2015 time series for total eHANPP by summing the agricultural and forestry series, after repeating the last observed values forwards (agriculture) and backwards (forestry) in time.

According to these data, global eHANPP was 13.2 Gt y^{-1} in 2007, which leads to an estimated planetary boundary for eHANPP of 13.2 + 5.0 = 18.2 Gt C y^{-1} (excluding human-induced fires and infrastructure). We divided the planetary boundary for eHANPP by world population for each year in our analysis. These methods can be directly compared to the approach taken by O'Neill et al.[1], but it is important to acknowledge that, although the new boundary for land-system change defined by Steffen et al.[24] is currently being transgressed, the global boundary for eHANPP is not[15]. In part this reflects the difference between a stock-based indicator (forest area) and a flow-based indicator (eHANPP), as well as the inclusion of agriculture within eHANPP. Given these differences, the boundary based on eHANPP may be viewed as less strict than the boundary based on forest area defined by Steffen et al.[4]

1.4 Ecological Footprint

The ecological footprint measures how much biologically productive land and sea area a given population requires to produce the natural resources it consumes and to absorb its waste, especially carbon emissions[26]. It is the sum of six components (cropland, forest land, fishing grounds, grazing land, built-up land, and carbon land), and can be compared to biocapacity, which measures the biologically productive land and sea area needed to regenerate all the human demands that compete for a given space (including biotic resources, accommodating houses and roads, and absorbing CO_2 emissions from fossil fuels). The global ecological footprint per capita surpassed global biocapacity per capita in the late 1960s[26].

Although the ecological footprint is not part of the planetary boundaries framework, it is a well-known sustainability indicator that we include for comparison, following O'Neill et al.'s[1] approach. This approach is also consistent with Wiedmann and Barrett's[27] survey-based findings that the indicator is most useful as part of a "basket" of indicators.

We compare a country's per capita ecological footprint to an equal per capita share of global biocapacity. Notably, this approach assumes that all biocapacity is available for use by people. National time series ecological footprint and biocapacity data were obtained from the Global Footprint Network[28]. The ecological footprint data account for trade by adding imports and subtracting exports (resulting in a measure of apparent consumption).

1.5 Material Footprint

The material footprint, also known as "raw material consumption" (RMC), measures the amount of used material extraction (minerals, fossil fuels, and biomass) associated with the final demand for goods and services, regardless of where that extraction occurs[29]. It includes the upstream (embodied) raw materials related to imports and exports, which are currently estimated to be three times higher than the direct volume of material resources traded across countries[30]. Like the ecological footprint, it is an indicator that does not link directly to a planetary boundary. However, we include it in our analysis as material use is an important indicator of the environmental pressure exerted by socioeconomic activities, and we compare it to a global boundary of 50 Gt y^{-1}, following O'Neill et al.'s[1] method. Global material flows crossed this boundary in the late-1990s[31].

Although the 50 Gt y^{-1} maximum sustainable level has a degree of arbitrariness, it has been proposed independently by various authors[32–35]. For instance, Dittrich et al.[33] suggest that global material extraction should not exceed 50 Gt y^{-1}, and propose a per capita limit of 8 t y^{-1} by 2030. This limit was also adopted in a high-profile analysis of the sustainability of humanity's environmental footprint[32], while UNEP's International Resource Panel recommends a per capita target of 6–8 t y^{-1} by 2050[34]. An analysis by Bringezu[35], which uses higher population growth projections, suggests a per capita target value of 5 t for the year 2050, with a range of 3–6 t. This target value is based on a return to year 2000 material use, which was 50.8 Gt. We adopt the same global target of 50 Gt y^{-1} selected by O'Neill et al.[1], which is a common denominator across the above analyses, although we caution that the literature is not very mature in this area. National time series material footprint data were obtained from the UNEP International Resource Panel's Global Material Flows Database[36], which uses the Eora MRIO Database[6,7] to estimate material flows.

1.6 Other Boundaries

Biosphere integrity is not explicitly included in the analysis due to the large difficulty in measuring and downscaling both functional and genetic diversity. Although several studies have made recent advances by linking estimates of endemic extinctions to global MRIO databases[37–41], there are no time series estimates of "biodiversity footprints" available for a large number of countries to date. Similarly, there is a lack of reliable national time series data on consumption-based freshwater use for a large number of countries on an annual basis[42,43], let alone a monthly basis[44] (which is the temporal resolution recommended by Steffen et al.[4] to take into account regional pressures). That being said, we are able to include *global* freshwater use in Figure 1 of the main text, using data obtained from Steffen et al.[45]

Following O'Neill et al.[1], we have not included the stratospheric ozone boundary because (a) the emission and management of ozone-depleting substances lies outside the scope of the decision-making of the average person, and (b) the Antarctic ozone hole is recovering as a result of the Montreal Protocol[46]. Ocean acidification is not included as a separate boundary since it is driven by climate change, and is thus already fully accounted for in the analysis (Section 1.1). According to Steffen et al.[4], the ocean acidification boundary "would not be transgressed if the climate-change boundary of 350 ppm CO_2 were to be respected".

2. Establishing Social Thresholds

In general, the data required to establish social performance relative to social thresholds over the 1992–2050 period tend to be more up-to-date but also sparser compared to the biophysical indicators. Only countries with populations greater than 1 million people were included. The following sub-sections provide details on each social indicator used in our analysis.

2.1 Life Satisfaction

The most widely used measure of perceived well-being is probably life satisfaction, which relates well-being to an individual's subjective appraisal of how his or her life is going[47]. To construct a national time series for the largest number of countries possible over the 1992–2015 period, we collected a single life satisfaction measure from four well-known databases, namely the *World Happiness Report*[48], the *World Values Survey*[49], the *European Values Survey*[50], and the *Eurobarometer*[51].

These data sources ask slightly different questions and use different response scales. The *World Happiness Report* collects data on a 0–10 scale on a nearly annual basis for ~100–150 nations from 2005 to 2018, based on the Cantril ladder question: "Please imagine a ladder, with steps numbered from 0 at the bottom to 10 at the top. The top of the ladder represents the best possible life for you and the bottom of the ladder represents the worst possible life for you. On which step of the ladder would you say you personally feel you stand at this time?" The *World Values Survey* and the *European Values Survey* both collect data on a 1–10 scale in 6-year waves for ~50–90 nations from 1981 to 2014, based on the question: "Overall, how satisfied are you with your life as a whole these days?" The *Eurobarometer* survey collected data on a 1–3 scale on a nearly annual basis for ~15 European nations from 1973 to 2002, based on the question: "Taking all things together, how would you say things are these days, would you say you're very happy, fairly happy, or not too happy?"

In order to maximise country coverage in the earlier years of the time series (i.e. before 2005) while minimising cross-survey differences, we developed a process to use as much information as possible from proximate years within the same country. As the *World Happiness Report* has the largest country coverage in more recent years, these data were used as the standard. The other surveys were transformed to the 0–10 scale, and re-scaled to account for structural variation across surveys within a given country based on observed response differences in overlapping values in the same year. Countries with missing values were interpolated linearly if the interval was less than 4 years. These methods yielded a sample of 45 countries with life satisfaction time series for the entire 1992–2015 analysis period, and 119 countries for the more recent 2005–2015 period. Following O'Neill et al.[1], a value of 6.5 out of 10 was chosen to represent the minimum threshold for this indicator.

2.2 Life Expectancy

We measure physical health using "life expectancy at birth", an indicator that measures the number of years a newborn infant could expect to live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life. Life expectancy is increasing in many countries at a rate that outpaces both economic and resource use growth, suggesting that high life expectancy can be achieved at lower levels of resource use over time[52,53]. We have set the life expectancy threshold at 74 years, which is broadly comparable to the threshold of 65 years of "healthy life expectancy at birth" proposed by O'Neill et al.[1], as discussed in the Methods of the main text. In 2015, nearly 50% of the countries for which data were available for this indicator had already achieved the threshold. We collected life expectancy data from the World Bank's *World Development Indicators*[11], which are available on an annual basis over the 1992–2015 period for virtually all of the countries included in our analysis (N = 145).

2.3 Nutrition

Following O'Neill et al.[1], we measure nutrition using the "food supply" indicator compiled by the UN Food and Agriculture Organization[54]. This indicator is measured in kilocalories (kcal) per capita and per day, and represents an average calorific intake of food and drink. The physiological requirements for the average adult range between 2100 and 2900 kcal per day (for average women and men, and moderate physical activity). Several factors influence nutritional requirements, including age, sex, body weight, level of activity, and physiological status (for example pregnancy and lactation)[55]. It would be preferable to use an indicator that takes into account these factors directly alongside non-calorific requirements (e.g. micronutrients) by measuring the population-wide prevalence of moderate or severe food insecurity tracked by SDG Indicator 2.1.2, but such data are not available for a large number of countries over our analysis period[56]. Instead, we have used 2700 kcal per person per day as a population-wide threshold for our time series analysis, which is the same value adopted by O'Neill et al.[1]

2.4 Sanitation

The sanitation indicator in our analysis measures the percentage of the population using improved sanitation facilities that ensure hygienic separation of human excreta from human contact, including facilities such as composting or flush/pour toilets (to a piped sewer system, septic tank, pit latrine) and pit latrines. A staggering 2.4 billion people lack access to improved sanitation facilities, with nearly 1 billion people practicing open defecation in 2015[57]. Although the proportion of the global population without access to improved sanitation facilities declined from 48% to 32% between 1990 and 2015, the absolute number of people has remained roughly stable (due to population growth). Although we believe that 100% of the population should have access to improved sanitation facilities because it is a fundamental aspect of a life free of deprivation, we have chosen a threshold of 95% for this indicator in recognition of the difficulty associated with extending universal access to the last 5% of a population, often located in very rural areas (few countries have actually achieved this goal). The data used in our analysis cover the 1990–2015 period, and they were collected from *Our World in Data*[57], although they are originally sourced from the World Bank's *World Development Indicators.* This specific indicator is no longer available from the *World Development Indicators*[11] database — it has been replaced by a similar indicator, "proportion of people using at least basic sanitation", but this latter indicator is not available before the year 2000.

2.5 Income Poverty

The first of the Sustainable Development Goals aims to "end poverty in all its forms everywhere"[58]. However, we believe the indicator used to measure progress on the eradication of extreme poverty — currently measured as $1.90 per day using 2011 international prices (SDG Indicator 1.1.1) — is far too low to represent a reasonable minimum threshold[59,60]. For a stark example, there is broad consensus that adequate nourishment is a precondition for escaping poverty, yet the number of people below the $1.90 per day international poverty line was less than the number of undernourished people worldwide in 2015 (10% and 11% of the global population, respectively[61]). Instead, we define a poverty threshold of $5.50 a day (using 2011 international prices), which is approximately the average of national poverty lines worldwide[62]. As noted in the Methods of the main text, however, it would be preferable to use an alternative indicator for measuring poverty based on country-specific baskets of essential goods and services[63,64], but such data do not exist for enough countries over our analysis period.

We collected data from the World Bank's *World Development Indicators*[11]*.* Given that the data are relatively sparse and not available for most high-income countries, we calculated the 1992–2015 time series in three steps that distinguish between high-income and low/middle-income nations. First, we excluded any countries with observations that only began after 2000, or that ended before 2005, unless they were high-income countries (as defined by the World Bank[11]). We included all high-income countries irrespective of missing values except for 7 countries who joined the high-income group over the analysis period (Chile, Estonia, Lithuania, Latvia, Panama, Romania, and Trinidad & Tobago). Second, we filled missing values by linear interpolation for each country, with first (last) observations carried backward (forward). Finally, if any of the remaining missing values were high-income countries, they were assigned a value of 95%, which is the average for high-income countries in the sample. These filters and transformations yielded a panel of 114 countries over the 1992–2015 period.

Although the goal is to have 100% of the population living above the $5.50 a day line, we use O'Neill et al.'s[1] threshold value of 95% in our analysis, given that not many countries report this indicator above 95%. In effect, we assume that values above 95% are equivalent to eradicating income poverty.

2.6 Access to Energy

Nearly 1 billion people currently do not have access to electricity, while 3 billion people rely on wood or other biomass to cook food, resulting in close to 4 million deaths per year that are attributable to indoor air pollution[65]. The data used in our analysis measure the percentage of the national population with access to electricity. They were obtained from the World Bank's *World Development Indicators*[11]. Although there are observations available for a large number of countries, the data are sparser in earlier years. We dropped any countries with observations that began after 2000 and filled missing values by linear interpolation for each country, with first (last) observations carried backward (forward). These filters and transformations yielded a panel of 130 countries over the 1992–2015 period. Following O'Neill et al.[1], and similar to the other percentage indicators, a threshold of 95% electricity access was used.

2.7 Education

Following O'Neill et al.[1], secondary school enrolment was chosen as our education indicator. Universal secondary education is widely recognised as a fundamental driver of development (SDG 4), and it is also deeply connected to achieving gender equality (SDG 5). There is evidence suggesting that women in developing countries who complete secondary education average at least one child fewer per lifetime than women who only complete primary education[66]. The data used in our analysis measure gross enrolment in secondary education (i.e. the ratio of total enrolment, regardless of age, to the population that are of secondary-school age). Ideally, we would have used net enrolment data (i.e. the ratio of enrolled children who are of secondary-school age, to the population that are of this age). However, these data were not available for as many countries. The result is that some countries can achieve more than 100% enrolment using the gross enrolment indicator, although it is not commonly observed. The data are from the World Bank's *World Development Indicators*[11]. Similar to the other social indicators, we drop countries with no observations before 2000 or that end before 2005 and interpolate missing values, yielding a panel of 137 countries over the 1992–2015 period. Following O'Neill et al.[1], a threshold of 95% was chosen for this indicator, in recognition that universal access to education does not imply 100% enrolment.

2.8 Social Support

The link between social support and achieving long, happy, and healthy lives was firmly established nearly fifty years ago[67]. Following O'Neill et al.[1], the social support indicator used in our analysis is a measure of whether or not people have someone to count on in times of need. It is the national average of binary responses (either 0 or 1) to the question "If you were in trouble, do you have relatives or friends you can count on to help you whenever you need them, or not?" The data are from the Gallup World Poll, as published in the *World Happiness Report*[48]. In contrast to all of the other indicators in our analysis, the social support time series is only available for a large number of countries starting in 2005, rather than 1992, so this indicator is excluded from cross-country comparisons of the total number of social thresholds achieved (i.e. Figures 2 and 3 in the main text). We excluded countries with no observations before 2007 and filled in missing values for each country by linear interpolation, yielding a panel of 118 countries over the 2005–2015 period.

Following O'Neill et al.[1], a value of 0.9, or 90%, was chosen as the minimum threshold for this indicator. This choice, which is lower than the other percentage indicators, was based on the identification of two confounding factors. First, reducing the complexity of a respondent's close relationships into a simple yes/no question likely leads to responses based on the availability heuristic, which is biased towards emotionally charged memories[68]. Second, the data do not differentiate between long-term, involuntary social isolation and short-term lack of social support, which may be voluntary (i.e. moving to a new region for work).

2.9 Democratic Quality

Democratic rights such as free association, free speech, and transparent policy-making are vital for enabling social participation and personal autonomy[69], and for guarding against discourses that reinforce structures of elite power entrenched in the status quo[70]. Following O'Neill et al.[1] and the *World Happiness Report*[48], the indicator of democratic quality used here is comprised of an unweighted average of two indicators obtained from the *Worldwide Governance Indicators* database[71]: voice and accountability, and political stability. These indicators are available from 1996 for a large number of countries, and they are built upon multiple sources (e.g. household surveys and interviews with experts, firms, and non-governmental organisations), and are presented on an ordinal scale between roughly -2.7 (poor democratic quality) and 1.7 (strong democratic quality)[72].

To construct the democratic quality time series used in our analysis, we transformed the original *Worldwide Governance Indicators* data to a ratio scale between 0 and 10, excluded countries with observations beginning only after 2000, filled missing values by linear interpolation for each country, and carried the first observation backward to 1992. These filters and transformations yielded a panel of 143 countries over the 1992–2015 period. We have chosen a threshold of 7 out of 10 for this indicator, which is roughly equivalent to the threshold chosen by O'Neill et al.[1] (although the authors did not rescale the values to a 0–10 scale, so their threshold value of 0.8 is not directly comparable).

2.10 Equality

Evidence for high-income countries suggests that more equal societies have fewer health and social problems than less equal ones[73]. Following O'Neill et al.[1], we chose the Gini coefficient as our measure of equality, using equivalised (square root scale) household disposable income (i.e. after taxes and transfers). The data are from the *Standardized World Income Inequality Database* (v8.1)[74]. Similar to the other social indicators, we excluded countries with no observations before 2000 or that end before 2005 and interpolated missing values, which yields a panel of 124 countries over the 1992–2015 period. A maximum Gini coefficient of 0.30 was chosen as our threshold, which is the same value selected by O'Neill et al.[1] To be consistent with our convention of a higher value on the social indicators representing better performance, we calculated equality as one minus the Gini coefficient (thus the threshold is a minimum of 0.70). The threshold value falls in between the Gini coefficients associated with "low" and "medium" total income inequality (0.26 and 0.36, respectively), as characterised by Piketty[75]. It also roughly corresponds to the level observed in the United States during the late-1970s.

2.11 Employment

The Sustainable Development Goals aim to achieve full employment and decent work with equal pay (SDG 8.5)[58]. Employment enables social and economic autonomy[69], and has been shown to be a strong determinant of subjective well-being[47]. Following O'Neill et al.[1], we measure employment as one minus the unemployment rate, where the latter refers to the share of the labour force that is without work but available for and seeking employment. To ensure comparability among countries, we use harmonised unemployment data from World Bank's *World Development Indicators*[11], which are available for all 148 countries included in our analysis over the 1992–2015 period. We chose a threshold of 6% unemployment (i.e. 94% employment) as corresponding to full employment in our analysis, which is the same threshold chosen by O'Neill et al.[1]

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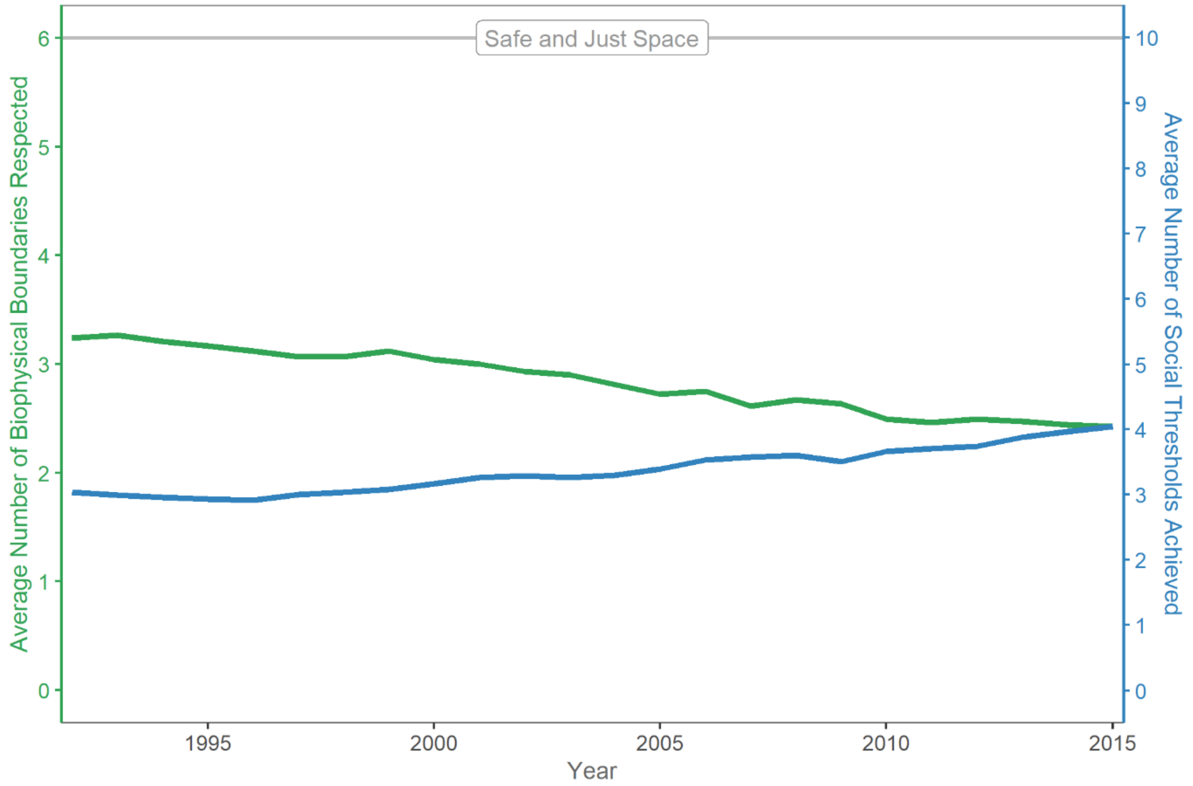
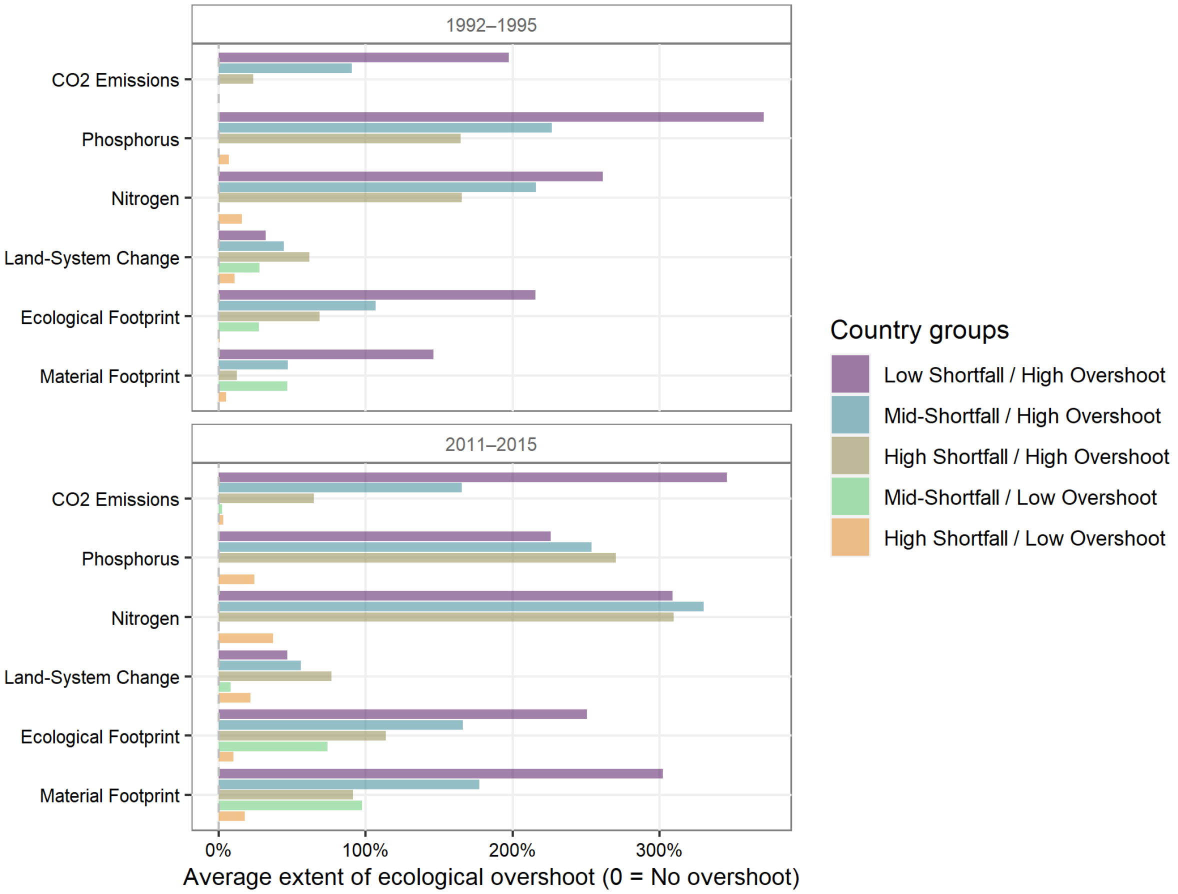
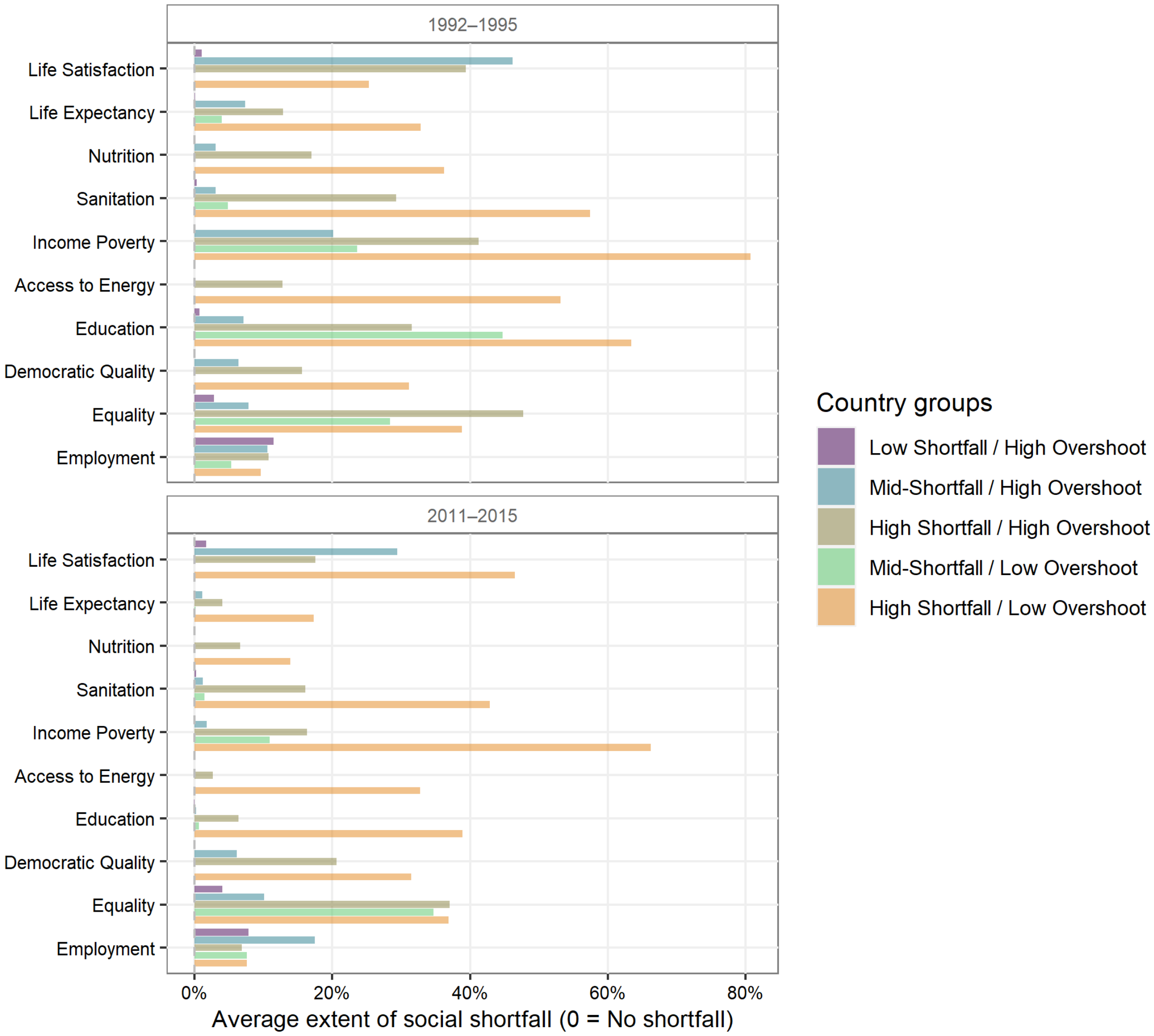
Supplementary Figures



Supplementary Figure 1. Average number of biophysical boundaries respected and social thresholds achieved per country (1992–2015). Average values are calculated from the sample of countries with data for all six biophysical indicators, and at least 9 of the 10 social indicators that span the analysis period (*N* = 91). Ideally, countries would achieve all social thresholds while respecting all biophysical boundaries, as indicated by the "Safe and Just Space" line at the top of the figure.



Supplementary Figure 2. Average extent of ecological overshoot by country group for each biophysical indicator in two periods. Country groups as per Figures 2 and 3 in the main text. If there is no country group bar shown for a given biophysical indicator, then this group has no ecological overshoot in this period.



Supplementary Figure 2. Average extent of social shortfall by country group for each social indicator in two periods. Country groups as per Figures 2 and 3 in the main text. If there is no country group bar shown for a given social indicator, then this group has no social shortfall in this period.

Supplementary Tables

Supplementary Table 1. Data sources for the biophysical indicators used in the analysis

Indicator	**Time Series**	**Source**	**Description**
CO_2 Emissions	1850-2015	PRIMAP-Hist (v2.1)[8] and Eora MRIO database[6,7]	Consumption-based allocation of CO_2 emissions from energy and cement production.
Phosphorus	1970-2010	Bouwman et al.[12], Oita et al.[13], and Eora MRIO database[6,7]	Consumption-based allocation of phosphorus from applied fertilizer.
Nitrogen	1970-2010	Bouwman et al.[12], Oita et al.[13], and Eora MRIO database[6,7]	Consumption-based allocation of nitrogen from applied fertilizer.
Land-System Change	1986-2015	Roux et al.[21] and Kastner et al.[25]	Consumption-based allocation of the human appropriation of net primary production (HANPP) embodied in final biomass products.
Ecological Footprint	1970-2015	Global Footprint Network[28]	Biologically productive land and sea area needed to regenerate the human demands that compete for that space, including biotic resources and infrastructure, and absorbing CO_2 emissions from fossil fuels.
Material Footprint	1990-2015	UNEP Global Material Flows database[36]	Consumption-based allocation of used raw material extraction (minerals, fossil fuels, and biomass).

Supplementary Table 2. Data sources for the social indicators used in the analysis.

Indicator	Time Series	Source	Description
Life Satisfaction	1973-2015	World Happiness Report[48], World / European Values Survey[49,50], Eurobarometer[51]	Responses to the life satisfaction questions of each survey, transformed using the Gallup World Poll's Cantril life ladder question (0–10 scale) as a benchmark.
Life Expectancy	1970-2015	World Bank[11]	Number of years a newborn infant could expect to live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life.
Nutrition	1970-2013	FAOSTAT[54]	Average calorific intake of food and drink per day, measured in kilocalories per capita.
Sanitation	1990-2015	World Bank[11]	Percentage of the population using improved sanitation facilities.
Income Poverty	1987-2015	World Bank[11]	Percentage of the population living on more than \$5.50 a day.
Access to Energy	1990-2015	World Bank[11]	Percentage of the population with access to electricity.
Education	1970-2015	World Bank[11]	Total enrolment, regardless of age, as a percentage of the population that are of secondary-school age.
Social Support	2005-2015	World Happiness Report[48]	National average of responses to the question "If you were in trouble, do you have relatives or friends you can count on to help you whenever you need them, or not?"
Democratic Quality	1996-2015	Worldwide Governance Indicators[71]	Average of two Worldwide Governance Indicators: voice and accountability, and political stability.
Equality	1970-2015	Standardized World Income Inequality Database[74]	Gini coefficient of household disposable income (i.e. after taxes and transfers).
Employment	1991-2015	World Bank[11]	Percentage of the labour force that is employed.