# *Supplementary information:*

*Human well-being in the Anthropocene: limits to growth*

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## Abstract

This technical note contains supplemental material to *Human well-being in the Anthropocene: limits to growth* This includes data selection, sources, and analysis. Much of the information is also available in the 2018 report to the Club of Rome (Randers et al., 2018) as well as in the Empirical Bases for the Earth3 Model (Collste et al., 2018).

## Introduction: Data selection and sources

Transparent world models require simple yet responsive indicators. Our choices of indicators to assess achievements on SDGs 1 to 7 were based first on the goal formulations in the UN 2030 Agenda resolution (United Nations, 2015). Where these formulations are not compatible with quantitative system modelling, we drew upon the *SDG Index and Dashboards Reports* (Sachs et al., 2016, 2017). As we wanted to combine a global and regional focus, we were also constrained by the availability of historical data. 2015 was the most recent year for which data were available for both our suite of SDG indicators and the planetary boundaries processes (the latter used for the wider Earth3 model; Randers et al., 2018, 2019; Goluke et al., 2018; Collste et al., 2018). Most fundamentally, we chose indicators that were straightforward and comprehensible for an interested public in order to make our analysis, and the *Earth3* model, as accessible as possible. The data sources we came to use are all publicly available via the *World Bank* and UN population statistics. For the GDP tracker, we used the also publicly available Penn World Tables’ *Real GDP measured in expenditures in PPP-adjusted 2011 USD* (RGDPe), which is suitable *“to compare relative living standards across countries and over time”* (Feenstra et al., 2015). The regional data is weighted by population size when aggregating (the primary) national data to regional levels.

Table 1 lists the modelled indicators we have used to track the degree to which the 7 SDGs are achieved, by region. Details on each SDG is presented in section 2 below. We use the seven world regions as specified in section 3.

|  |  |  |
| --- | --- | --- |
| **SDG** | | **Indicator** |
| ***The 17 goals for humanity agreed by the UN in 2016*** | | ***Indicator for the achievement of each Sustainable Development Goal*** |
| **1** | **No poverty** | Fraction of population living below 1.90$ per day (%) |
| **2** | **Zero hunger** | Fraction of population undernourished (%) |
| **3** | **Good health** | Life expectancy at birth (years) |
| **4** | **Quality education** | School life expectancy (years) |
| **5** | **Gender equality** | Gender parity in schooling (1) |
| **6** | **Safe water** | Fraction of population with access to safe water (%) |
| **7** | **Enough energy** | Fraction of population with access to electricity (%) |

Table 1: The SDG and the chosen indicators.

## Data analysis of the 17 SDGs

In general, the following procedure has been followed with some alterations for the different SDGs as specified under each goal:

* We portray the historical data as a function of GDP per person (GDPpp, measured in 2011 Purchase Power Parity, PPP, adjusted US$). Country data has been averaged over five-year periods. As there are shortages of historical data for many countries, we have averaged the numbers based on the population sizes of countries where data is available, as part of the respective regions.

#### SDG1 – No poverty

For *SDG1 – No poverty* we use the commonly used definition *Fraction of population living below 1.90$ per day*. The SDG target is to “eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day” (United Nations, 2015). In the latest World Bank data this has however been updated to $1.90 per day using 2011 international prices. This indicator is also included in the *SDG Index and Dashboards Report* (Sachs et al., 2017) in relation to SDG1. Furthermore, data availability is good. We have retrieved data per region from the World Bank (referred to as Poverty headcount ratio at $1.90 a day (2011 PPP) (% of population), World Bank, 2018d) for the following years for the respective regions (displayed in manuscript):

* 1980–2015:
  + United States
* 1985–2015:
  + Other Rich Countries
  + Emerging Economies
  + Indian Subcontinent
  + Africa South of Sahara
* 1990–2015
  + China
  + Rest of World

The threshold values of 2 and 13 are based on the *SDG Index and Dashboards Report 2017*vi.

#### SDG2 – Zero hunger

For SDG2 – Zero hunger we use the indicator *Fraction of population undernourished*. Undernourishment is also used as one of the indicators in the *SDG Index and Dashboards Report* 2017. We have obtained three data points for all regions, for 2000–2015, retrieved from the World Bank (World Bank, 2018e).The original source is *Food and Agriculture Organization (fao.org/publications/en)*. The threshold levels of 7 and 15 are based on the SDG

Index and Dashboards Report 2017 (Sachs et al., 2017).

#### SDG3 - Good health

For SDG3 – Good health we use the indicator *Life expectancy at birth*. Data is retrieved from the UN Population Division and exists from 1965 (United Nations, Department of Economic and Social Affairs, Population Division, 2019) and is portrayed in the manuscript. The SDG Index and Dashboard Report 2017 (Sachs et al., 2017) includes a similar variable, *Healthy life expectancy at birth*. We found data availability for *healthy life expectancy* not as good as for *life expectancy*. Our threshold values of 70 and 75 years are based on *SDG Index and Dashboards Report* 2017 and the average difference between data for *Life expectancy* and *Healthy life expectancy* for different countries.

#### SDG4 – Quality education

For SDG4 – Quality education we use the indicator *School life expectancy, primary to tertiary, both sexes* as our indicator. *School life expectancy* is included in the calculations of the Human Development Reports and the *SDG Index and Dashboards Report* 2017 (Sachs et al., 2017). The threshold levels of 10 and 12 are consistent with the *SDG Index and Dashboards Report* 2017. It also corresponds well with the explicit mentioning of secondary education in the 2030 Agenda resolution. We retrieved the data from the World Bank (World Bank, 2018b) for 1980–2015 for all world regions.

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#### SDG5 - Gender equality

For SDG5 – Gender equality we use *School life expectancy, primary to tertiary, gender parity index (GPI)* as our indicator. The data was retrieved from the World Bank (World Bank, 2018b) for 1980–2015 for all world regions except United States (1985–2015) and Rest of World (1995–2015) and is portrayed in the manuscript. Note that we use the indicator *expected years of schooling* and *not* years of schooling for both SDG5 and SDG4. Gender parity of expected years of schooling is the expected years of schooling for women, divided by the expected years of schooling for men. A value of 1 indicates that both men and women have the same expected years of schooling, a value below 1 indicates that men have higher expected years of schooling and a value above 1 that women have higher expected years of schooling. The SDG Index and Dashboards Report 2017 includes the similar variable Female years of schooling (% male) and suggests the threshold values of 75% and 98% (corresponding to the gender parity index of 0.75 and 0.98 respectively). We use 0.80 and 0.95.

#### SDG6 – Safe water

For SDG6 – Safe water we use *People using at least basic drinking water services (% of population)* as our indicator. The original data source is *WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply, Sanitation and Hygiene (washdata.org)*. We retrieved the data from the World Bank (World Bank, 2018c) for 2000–2015 for all regions except United States and Rest of World (both 2005–2015), and are plotted in the manuscript. The *SDG Index and Dashboards Report* 2017 (Sachs et al., 2017) includes the similar indicator: *Access to improved water*. We use the threshold values that the *SDG Index and Dashboards Report* 2017 suggest for this indicator, 80% and 98%. Note the limitations implied in using access indicators, such as those for SDGs 6 and 7, as there is a risk that issues of safety, reliability, affordability and sustainability are ignored. These are however more difficult to model in a simple and straightforward manner given the scope of our analysis.

#### SDG7 – Enough energy

For SDG7 we use the indicator *Access to electricity (% of population)* that we retrieved from the World Bank (World Bank, 2018a) for 1990–2015 for all our regions, see plot in manuscript. Access to electricity is also included as an indicator for SDG7 in the *SDG Index and Dashboards Report* 2017 (Sachs et al., 2017). We use the same threshold values as in the *SDG Index and Dashboards Report* 2017, 80% and 98%.

## Specification of the seven regions

We developed a regional database of historical performance on all SDG indicators and analyzed the relationships between historical income levels and outcomes on the human-needs SDGs. We used seven world regions and the world as a whole, giving us eight geographic categories.

For national economic data we have used the Penn World Tables, version 9 (Feenstra et al., 2015), that is available for download at [www.ggdc.net/pwt](http://www.ggdc.net/pwt). All GDP data are in 2011 PPP $, in the table below 2011 PPP G$/y. (1 G$ = 1 billion $ = 1000 million $.) Population data is from UN Population Division: <https://esa.un.org/unpd/wpp/DataQuery/> (United Nations, Department of Economic and Social Affairs, Population Division, 2019)

We have used seven regions for our analysis: United States, Other Rich Countries, Emerging Economies, China, Indian Subcontinent, Africa South of Sahara and Rest of World. The sequence in Table 2 follows an order of descending GDPpp per region average.

We have disregarded “region 8”, which consists of a few super-rich countries outside the OECD. This cluster of countries is small (<1% of world population), and they are statistical outliers that distort the analysis.

Table 2: Regionalization of the Earth3 model.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| REGION | Country | Population | GDP | GDPpp |
|  |  | 2015 | 2015 | 2015 |
|  |  | Mp | G$/y | $/p-y |
|  |  | UN | PWT | (=D/C) |
| 1. United States (USA) |  |  |  |  |
|  | US,  Including Puerto Rico and US Virgin Islands | 327 | 16 705 | *51 100* |
|  | ***SUM USA*** | ***327*** | ***16 705*** | ***51 100*** |
| 2. Other Rich Countries (ORC) |  |  |  |  |
|  | Australia | 23,8 | 1 017 | *42 700* |
|  | Austria | 8,7 | 407 | *46 800* |
|  | Belgium | 11,3 | 490 | *43 400* |
|  | Canada | 36,0 | 1 507 | *41 900* |
|  | Chile | 17,8 | 383 | *21 500* |
|  | Czech Republic | 10,6 | 336 | *31 700* |
|  | Denmark | 5,7 | 254 | *44 600* |
|  | Estonia | 1,3 | 38 | *29 200* |
|  | Finland | 5,5 | 221 | *40 200* |
|  | France | 64,5 | 2 603 | *40 400* |
|  | Germany | 81,7 | 3 707 | *45 400* |
|  | Greece | 11,2 | 286 | *25 500* |
|  | Hungary | 9,8 | 256 | *26 100* |
|  | Iceland | 0,3 | 14 | *46 700* |
|  | Israel | 8,1 | 264 | *32 600* |
|  | Italy | 59,5 | 2 141 | *36 000* |
|  | Japan | 128,0 | 4 483 | *35 000* |
|  | Luxembourg | 0,6 | 53 | *88 300* |
|  | Netherlands | 16,9 | 797 | *47 200* |
|  | New Zealand | 4,6 | 156 | *33 900* |
|  | Norway | 5,2 | 331 | *63 700* |
|  | Poland | 38,3 | 972 | *25 400* |
|  | Portugal | 10,4 | 296 | *28 500* |
|  | Slovakia | 5,4 | 155 | *28 700* |
|  | Slovenia | 2,1 | 63 | *30 000* |
|  | South Korea | 50,6 | 1 758 | *34 700* |
|  | Spain | 46,4 | 1 567 | *33 800* |
|  | Sweden | 9,8 | 433 | *44 200* |
|  | Switzerland | 8,3 | 480 | *57 800* |
|  | UK | 65,4 | 2 589 | *39 600* |
|  | ***SUM ORC*** | ***748*** | ***28 057*** | ***37 500*** |
| 3. Emerging Economies (EE) |  |  |  |  |
| Characteristic: big mid-income countries |  |  |  |  |
|  | Argentina | 43,4 | 869 | *20 000* |
|  | Brazil | 206,0 | 3 064 | *14 900* |
|  | Iran | 79,4 | 1 215 | *15 300* |
|  | Kazakhstan | 17,8 | 407 | *22 900* |
|  | Malaysia | 30,7 | 692 | *22 500* |
|  | Mexico | 125,9 | 1 988 | *15 800* |
|  | Russia | 143,9 | 3 448 | *24 000* |
|  | Romania | 19,9 | 409 | *20 600* |
|  | Thailand | 68,7 | 946 | *13 800* |
|  | Turkey | 78,3 | 1 491 | *19 000* |
|  | Ukraine | 44,7 | 465 | *10 400* |
|  | Venezuela | 31,2 | 434 | *13 900* |
|  | ***SUM EE*** | **890** | **15 428** | ***17 300*** |
| 4. China |  |  |  |  |
|  | Taiwan | 23,5 | 1 039 | *44 200* |
|  | China | 1 397,0 | 17 080 | *12 200* |
|  | Hong Kong | 7,3 | 374 | *51 200* |
|  | ***SUM CHINA*** | **1 428** | **18 493** | ***13 000*** |
| 5. Indian Subcontinent |  |  |  |  |
| Characteristic: poor and populous |  |  |  |  |
|  | Bangladesh | 161,2 | 459 | *2 800* |
|  | India | 1309,0 | 6 767 | *5 200* |
|  | Pakistan | 189,4 | 860 | *4 500* |
|  | ***SUM INDIAN SC*** | **1 660** | **8 086** | ***4 900*** |
|  |  |  |  |  |
| 6. Africa South of Sahara (ASoS) |  |  |  |  |
| Characteristic: poor and resource rich |  |  |  |  |
|  | Angola | 27,9 | 193 | *6 900* |
|  | Cameroon | 22,8 | 61 | *2 700* |
|  | Congo | 76,2 | 91 | *1 200* |
|  | Cote d'Ivoire | 23,1 | 74 | *3 200* |
|  | Ethiopia | 99,9 | 128 | *1 300* |
|  | Ghana | 27,6 | 96 | *3 500* |
|  | Kenya | 47,3 | 124 | *2 600* |
|  | Madagascar | 24,2 | 29 | *1 200* |
|  | Mozambique | 28,0 | 31 | *1 100* |
|  | Nigeria | 181,2 | 976 | *5 400* |
|  | Sudan | 38,6 | 190 | *4 900* |
|  | South Africa | 55,3 | 655 | *11 800* |
|  | Tanzania | 53,9 | 112 | *2 100* |
|  | Uganda | 40,1 | 69 | *1 700* |
|  | ***SUM AFRICA SoS*** | **746** | **2 829** | ***3 800*** |
| 7. Rest of the World – 120 (RoW) |  |  |  |  |
| Sum world (from other data) |  | 7 383 | 103 866 | *14 100* |
| Sum of regions 1–8 |  | 5 847 | 92 380 | *15 800* |
| = | ***SUM ROW 120*** | **1 536** | **11 486** | ***7 500*** |
|  |  |  |  |  |
| 8. Super-rich outside OECD |  |  |  |  |
| Characteristic: “authoritarian wealth” |  |  |  |  |
|  | Quatar | 2,5 | 314 | *125 600* |
|  | Saudi Arabia | 31,6 | 1 483 | *46 900* |
|  | Singapore | 5,5 | 400 | *72 700* |
|  | UAE | 9,2 | 585 | *63 600* |
|  | ***SUM SUPER-RICH*** | **49** | **2 782** | ***57 000*** |
| MEMO |  |  |  |  |
| The following countries have more than .3% of total population or GDP. That is >22Mp or >300G$/y |  |  |  |  |
| But have still been left in the Rest of World category |  |  |  |  |
|  | Afghanistan | 33,7 |  |  |
|  | Algeria | 39,9 | 499 | *12 500* |
|  | Colombia | 48,2 | 602 | *12 500* |
|  | Egypt | 93,8 | 888 | *9 500* |
|  | Indonesia | 258,2 | 2 470 | *9 600* |
|  | Iraq | 36,1 | 427 | *11 800* |
|  | Morocco | 34,8 | 243 | *7 000* |
|  | Myanmar | 52,4 | 286 | *5 500* |
|  | Nepal | 28,7 | 61 | *2 100* |
|  | North Korea | 25,2 |  |  |
|  | Philippines | 101,7 | 660 | *6 500* |
|  | Uzbekistan | 31,0 | 241 | *7 800* |
|  | Vietnam | 93,6 | 495 | *5 300* |
|  | Yemen | 26,9 | 88 | *3 300* |
|  | ***SUM BIG in ROW120*** | **904** | **6 960** | ***7 700*** |
|  |  |  |  |  |

## References

Collste, D., Randers, J., Goluke, U., Stoknes, P. E., Cornell, S., & Rockström, J. (2018). *The Empirical Bases for the Earth3 Model: Technical Notes on the Sustainable Development Goals and Planetary Boundaries* [Preprint]. EarthArXiv. https://doi.org/10.31223/osf.io/ephsf

Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The Next Generation of the Penn World Table. *American Economic Review*, *105*(10), 3150–3182. https://doi.org/10.1257/aer.20130954

Goluke, U., Randers, J., Collste, D., & Stoknes, P. E. (2018). *The Earth3 model system. Https://osf.io/a8mvf/*. https://osf.io/a8mvf/

Randers, J., Rockström, J., Stoknes, P. E., Golüke, U., Collste, D., & Cornell, S. E. (2018). *Transformation is feasible: How to achieve the Sustainable Development Goals within Planetary Boundaries. A report to the Club of Rome, for its 50 years anniversary 17 October 2018*. Stockholm Resilience Centre. https://www.stockholmresilience.org/publications/artiklar/2018-10-17-transformation-is-feasible---how-to-achieve-the-sustainable--development-goals-within-planetary-boundaries.html

Randers, J., Rockström, J., Stoknes, P.-E., Goluke, U., Collste, D., Cornell, S. E., & Donges, J. (2019). Achieving the 17 Sustainable Development Goals within 9 planetary boundaries. *Global Sustainability*, *Vol 2*(e24), 1–11. https://doi.org/10.1017/sus.2019.22

Sachs, J., Schmidt-Traub, G., Kroll, C., Durand-Delacre, D., & Teksoz, K. (2016). *SDG Index & Dashboards—Global Report* (SDG Index and Dashboards Report 2016). Bertelsmann Stiftung and Sustainable Development Solutions Network (SDSN). http://sdgindex.org/reports/2016/

Sachs, J., Schmidt-Traub, G., Kroll, C., Durand-Delacre, D., & Teksoz, K. (2017). *SDG Index and Dashboards Report 2017—Global Responsibilities: International spillovers in achieving the goals* (SDG Index and Dashboards Report 2017). Bertelsmann Stiftung and Sustainable Development Solutions Network (SDSN). http://sdgindex.org/reports/2017/

United Nations. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development, General Assembly resolution 70/1* (Resolution A/RES/70/1). undocs.org/en/A/RES/70/1

United Nations, Department of Economic and Social Affairs, Population Division. (2019). *World Population Prospects 2019: Volume I: Comprehensive Tables.* United Nations, Department of Economic and Social Affairs, Population Division.

World Bank. (2018a). *Access to electricity (% of population)*. https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS

World Bank. (2018b). *Education Statistics (EdStats)*. https://datatopics.worldbank.org/education/

World Bank. (2018c). *People using at least basic drinking water services (% of population)*. https://data.worldbank.org/indicator/SH.H2O.BASW.ZS

World Bank. (2018d). *Poverty headcount ratio at $1.90 a day (2011 PPP) (% of population)*. https://data.worldbank.org/indicator/SI.POV.DDAY

World Bank. (2018e). *Prevalence of undernourishment (% of population)*. https://data.worldbank.org/indicator/SN.ITK.DEFC.ZS