

1 Governance in socio-economic pathways and its role for 2 future adaptive capacity

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7 *Weak governance is one of the key obstacles for sustainable development. Undoubtedly, improvement of*
8 *governance comes with a broad range of co-benefits including countries' abilities to respond to pressing*
9 *global challenges such as climate change. However, beyond the qualitative acknowledgement of its*
10 *importance, quantifications of future pathways of governance are still lacking. This study provides*
11 *projections of future governance in line with the Shared Socio-economic Pathways (SSPs). We find that*
12 *under a "rocky road" scenario, 30% of the global population would still live in countries characterized by*
13 *weak governance in 2050, while under a "green road" scenario weak governance would almost be entirely*
14 *overcome over the same time frame. Based on pathways for governance, we estimate the adaptive capacity*
15 *of countries to climate change. Limits to adaptive capacity exist even under optimistic pathways beyond*
16 *mid-century. Our findings underscore the importance of accounting for governance in assessments of*
17 *climate change impacts.*

18
19 Future societies' resilience against global challenges such as climate change hinges upon
20 successful implementation of policies, actions and development strategies¹. Those actions need
21 to be facilitated by the quality and efficiency of governance, which makes governance an
22 essential ingredient for assessing countries future climate vulnerability and coping capacity².

23 More broadly, institutions and governance are key determinants of long-term stability and

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24 sustainable growth of nations³. Advancing human and economic development requires active and
25 effective governance capable of making relevant policy addressing present day challenges and
26 providing quality welfare and services⁴. This is also the focus of Sustainable Development Goal
27 (SDG) 16 (*Peace, Justice and Strong Institutions*), which aims at promoting the rule of law;
28 substantially reducing corruption, developing effective, accountable and transparent institutions
29 and building of institutional capacity at all levels⁵. Likewise, strengthening institutions to achieve
30 beneficial social outcomes is central to the fulfilment of other SDGs, such as ending poverty in all
31 its forms everywhere (SDG 1), achieving gender equality (SDG 5) and reducing inequality within
32 and among countries (SDG 10)⁵.

33

34 With respect to countries' capacity to adapt to climate change, good governance and institutions
35 have been identified as key conditions for the successful deployment of adaptation options^{2,6}. The
36 IPCC's Fifth Assessment Report (AR5) characterizes adaptation barriers (or constraints) as
37 "factors that make it harder to plan and implement adaptation actions or that restrict options".
38 Lack of institutional capacity is identified as the most pertinent constraint to adaptation across
39 many sectors (e.g. water, urban areas, human health, human security) and in all world regions².
40 The numerous interventions that may enable or hinder adaptation – such as prioritizing policies,
41 mobilizing resources, coordination of efforts, decision-making – are processes often contingent
42 on the efficacy of institutional mechanisms². A recent review of economic literature on adoption of
43 environmental policy, for instance, finds a positive relationship between policy adoption and
44 various indicators of institutional quality⁷. Inept governance can even hinder a country's ability to
45 realize adaptation goals and targets set according to the country's level of vulnerability⁸.
46 Countries with better governance are also found to be more likely to receive adaptation aid from
47 donors since it is assumed that adaptation funding will be used more effectively⁹.

48 In particular, the level of corruption within institutions, which is one of the main determinants of
49 the quality of governance, is highly relevant for climate change adaptation^{10,11}. In a country with
50 weak governance, investments in adaptation measures can potentially pose corruption risks¹².

51 There is evidence that the level of corruption such as bribery and misuse of resources can be
52 more severe in post-disaster operations as compared to the pre-disaster¹². Corruption weakens
53 institutions, damages public trust and the strength of social contract, diverts funds from budgets
54 and investments, interferes with the flow of development aid and hinders human capital
55 formation^{13,14}. Improving governance and strengthening anti-corruption measures thus is critical
56 for implementation of adaptation actions.

57 Understanding current and future evolution of governance is necessary for assessments of
58 adaptive capacity and thereby the impacts of future climate change. Insights into the temporal
59 evolution of adaptive capacity can also indicate the existence of limits to adaptation at a given
60 point in time. Quantification of adaptive capacity also has practical application in climate impact
61 models. Understanding governance outlook hence can reveal future challenges in climate change
62 adaptation.

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65 Governance in the Shared Socio-economic Pathways

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67 To operationalize and facilitate future climate impact assessments, the Shared-Socioeconomic
68 Pathways (SSP) scenarios have been developed. The pathways are categorized along the
69 assessed challenges to climate mitigation and adaptation. The five qualitative storylines describe
70 different characteristics of and interactions between natural resources, economy, demography,
71 lifestyle, human development, technology and institutions¹⁵. The SSPs provide a framework to
72 assess a wide range of possible futures and societal changes both between and within countries,
73 and the extent to which these conditions create challenges to mitigation and adaptation to climate
74 change. Some adaptation-relevant dimensions including population and education¹⁶,
75 urbanization¹⁷ and income¹⁸⁻²⁰ human development²¹ and inequality²² have already been quantified
76 in the SSP framework. A quantification of the SSPs in terms of future governance trajectories,
77 however, has not yet been realized.

78

79 The departure point for the quantification of an indicator of governance along the five SSPs is the
80 qualitative description in the scenarios' narratives¹⁵, captured by the characterization of
81 institutions and their effectiveness as outlined in Table 1. SSP1 is the "green road" scenario,
82 which envisages a rapid shift to sustainable development, increases in education and health
83 investments, declining inequality both within and between countries, and de-emphasis on
84 economic growth and reduction of resource intensity in favor of improving environmental
85 conditions. Institutions are expected to become increasingly effective and international
86 cooperation becomes persistent. Such features make the SSP1 world characterized by low
87 challenges to both climate mitigation and adaptation as a result of inclusive economic growth and
88 sustainable welfare. The "middle of the road" scenario SSP2 is characterized by uneven and
89 sluggish economic growth and development with slower progress towards achieving the SDGs.
90 SSP2 does not differ substantially from the present-day trends. SSP2 is largely consistent with
91 historical dynamics, but it takes into account dynamic relationships among socioeconomic
92 determinants and convergence between countries. Institutions in SSP2 are modestly effective and
93 uneven. SSP3, also termed the "rocky road" scenario, expects regional and global conflicts to
94 result from international fragmentation and inter-country rivalry. Countries are preoccupied with
95 national goals, which weakens international cooperation. Governance in SSP3 is rather ineffective
96 and support for international and development institutions is reduced. "A road divided" or SSP4
97 presents low challenges to mitigation thanks to global technological advancement but high
98 challenges to adaptation due to the unequal distribution of resources both within and across
99 countries. Governance is assumed to be stronger in high-income regions whilst in low-income
100 regions, basic human development is neglected and policy implementation is likely to be
101 unsuccessful due to weak governance. Higher inequalities result in weak representation of the
102 vulnerable groups and persistence of low levels of development. The SSP3 and SSP4 scenarios
103 present the highest challenges to adaptation, caused by the combination of slow development,
104 low education, high inequality and weak institutions. Finally, SSP5 is characterized by
105 development driven by fossil fuel-intensive economies which enable countries to become richer

106 and more equitable at the price of substantial environmental degradation. Similar to SSP1, the
 107 SSP5 scenario also assumes improved institutions and rapid human development, particularly for
 108 the currently disadvantaged populations. However, unlike in SSP1, the nature of the underlying
 109 growth in SSP5 relies heavily on fossil fuel use and results in high challenges to climate change
 110 mitigation¹⁵.

111

	SSP1	SSP2	SSP3	SSP4	SSP5
Governance	Effective	Modestly effective	Ineffective	Unequal within countries	Increasingly effective
Income	High	Medium	Very unequal between countries	Very unequal within and between countries	High
Higher education	High	Medium	Low	Unequal	High
Gender equality education	High	Medium	Low	Unequal within regions	High

112 *Table 1: Overview of representation of governance and its correlates in the five SSP scenarios.*

113

114 **Future pathways of governance**

115 In order to quantify and project governance trajectories along the SSPs scenarios, we rely on
 116 theoretical insights on the determinants of good governance for an empirical specification.
 117 Subsequently, an econometric model is employed to establish a relationship between governance
 118 and countries' socio-economic indicators of which projections along the five SSP scenarios are
 119 already available. Future projections of governance evolution within the SSP framework are then
 120 derived and can be used to evaluate the challenges to adaptation together with an internally
 121 consistent set of socioeconomic variables in the SSPs.

122

123 Given its breath and depth, governance (a dependent variable in our econometric model) and its
 124 dimensions can be conceptualized in many ways. Here we use the well-established Worldwide
 125 Governance Indicators (WGI) that provide a composite index for governance with six sub-
 126 categories: voice and accountability, political stability, government effectiveness, regulatory

127 quality, rule of law and control of corruption. The indicators presented in this database aggregate
128 perceptions of governance of a large number of enterprise, citizen and expert survey respondents
129 from 31 different data sources provided by 25 different organizations, and provide a broad
130 country coverage²³. The strength of the WGI in capturing an inherently complex concept lays in
131 its many different data sources that summarize information on the various dimensions of
132 governance, and through averaging the data on the country level control for the possible
133 idiosyncrasies between sources²⁴.

134
135 The choice of the determinants of good governance (our explanatory variables) is based on
136 modernization theory which posits that economic and educational development are central
137 determinants of improvements in the rule of law^{25,26}. There is, in addition, ample empirical
138 evidence of a causal relationship between female representation in government and reduced
139 levels of corruption²⁷, as well as a strong connection between gender empowerment and
140 democracy⁴. Within the SSP framework, economic as well as education trajectories are readily
141 available^{18,16}. For gender equality, we use the difference in mean years of schooling between men
142 and women a proxy variable. This measure of gender equality arguably represents only one
143 dimension of it, but gender gaps in education can be credibly taken as indicative of more
144 widespread gender inequality issues in a society.

145
146 The model (see Methods) is estimated using a panel data for 173 countries for the time period
147 from 1995 to 2015. Although governance indicators at the subnational level are available for a few
148 countries, the most granular SSP projections with global coverage for other socioeconomic
149 variables are only available at the country level, which also defines our unit of cross-sectional
150 variation.

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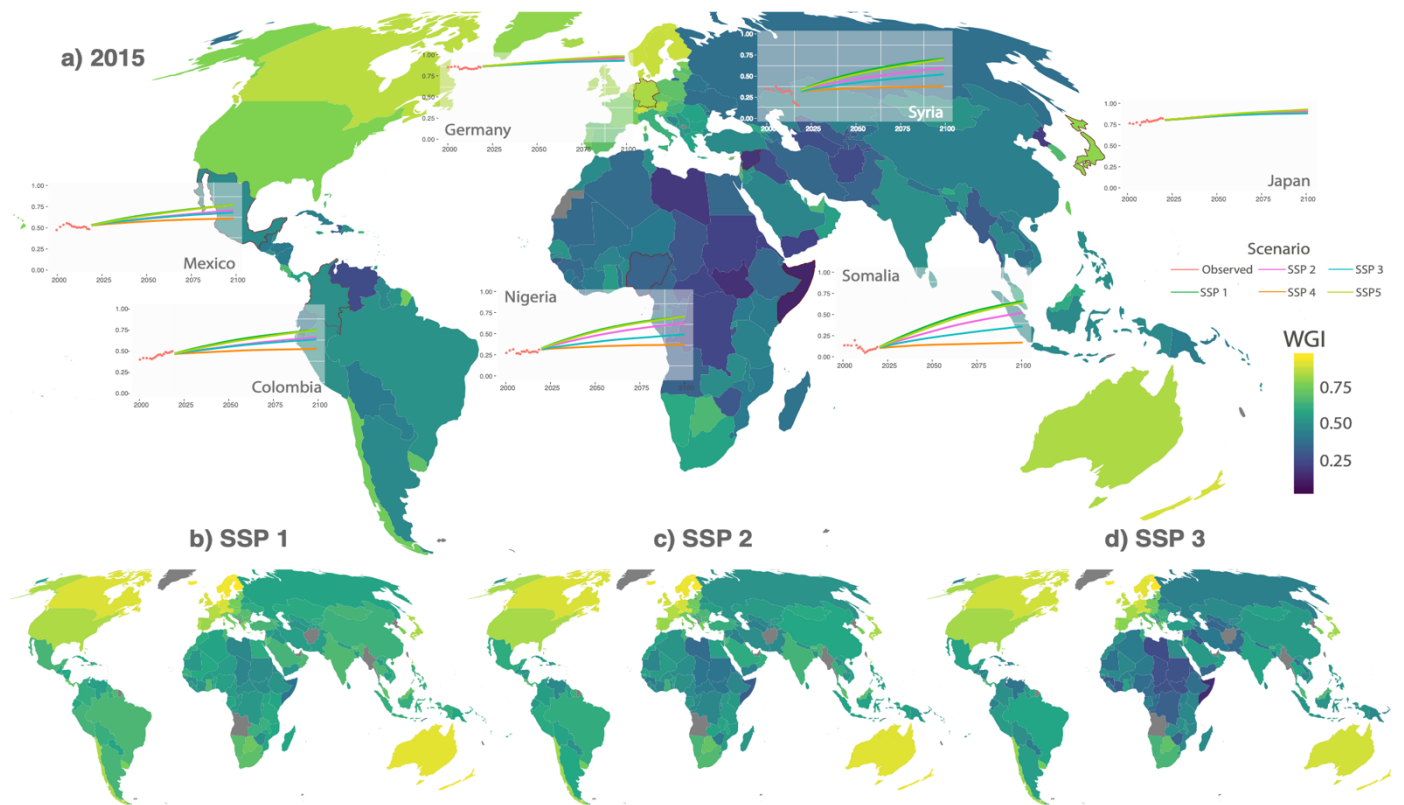


Figure 1: **Evolution of governance over the 21- century**

The 2015 values of the normalized composite world governance indicator (WGI) in 2015 are shown in **a**, overlaid with the scenario dependent evolution of governance for selected countries over the 21- century. The governance indicator is normalized to a range from 0 to 1, with higher values indicating better governance. The global distribution of future governance in 2050 is depicted for different SSPs ranging from a 'sustainable future' (SSP1, **b**) to a 'middle of the road' scenario (SSP2, **c**) and a 'rocky road' scenario characterized by unequal development and regional rivalry (SSP3, **d**).

152

153 Our econometric analysis shows that the aggregate governance indicator from the WGI
 154 database²³ can be well predicted using GDP per capita, the share of population with higher
 155 education and the gender gap in mean years of schooling (see Table 1 in Supplementary
 156 Information). The estimated elasticities linking the variables in the specification to changes in
 157 governance indicators appear robust to changes in the modelling strategy. The estimates
 158 obtained from the model are then combined with the available country-level indicators of socio-
 159 economic performance within the SSP framework to calculate projections of the governance
 160 indicators over the 21st century.

161

162 In line with the SSP narratives, future projections of governance show distinct differences
 163 between the scenarios (Figure 1). For developed countries such as Germany or Japan, whether
 164 the country follows the most or the least progressive scenario makes only a minor difference for

165 the dynamics of the projected governance indicator since their score remains very high in all
 166 scenarios. For less well-off countries, however, the path of the socio-economic development is
 167 decisive for how governance is expected to evolve (Figure 1 b,c,d): for countries like Somalia or
 168 Nigeria, the difference between following the SSP1 (“green road”) and SSP3 (“rocky road”) could
 169 result in anything from stagnation to trifold improvement.

170
 171 Under the SSP3 scenario, little improvement in governance is projected globally over the 21st
 172 century. In contrast, substantial progress already by mid-century is evident under the SSP1
 173 scenario which envisages a sustainable future. Similarities between SSP1 and SSP5 arise as a
 174 result of the almost identical representation of governance in the original storylines, which is
 175 reproduced in our projections. Although the development narrative and resulting climate
 176 mitigation challenges in SSP1 and SSP5 differ fundamentally, their socio-economic development
 177 trajectories are remarkably similar. SSP4 on the other hand, yields results that are in between
 178 SSP2 and SSP3. Because of these similarities, in two of the figures we report results for only for
 179 SSP1, SSP2 and SSP3.

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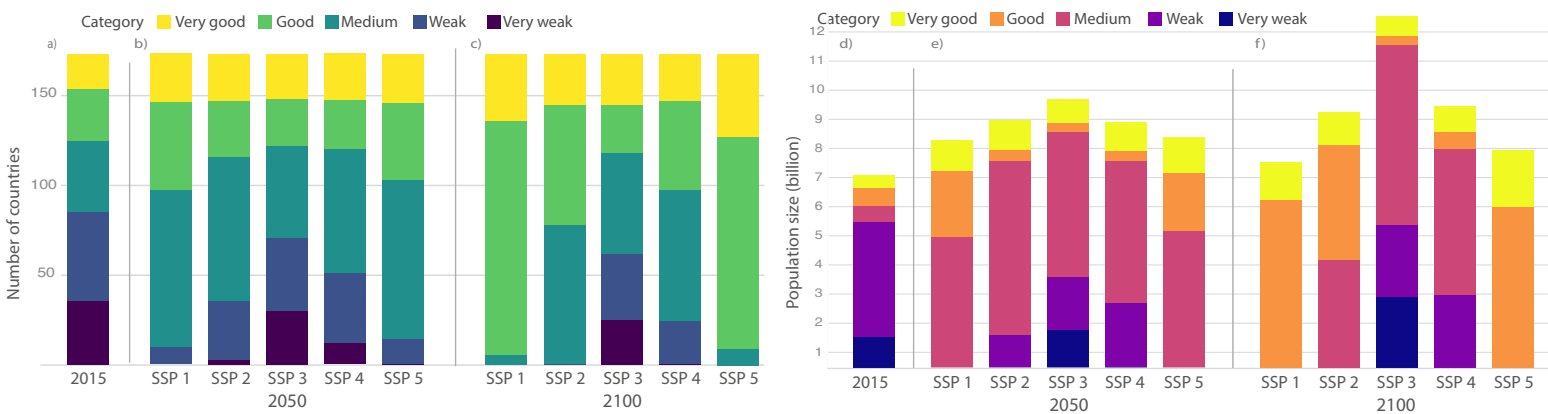


Figure 2: **Country groups and population-weighted projections**

a-c, The number of countries per SSP in different governance categories for 2015, 2050 and 2100, respectively. The governance indicator is normalized with 0 indicating very low levels of governance across all indicators and 1 indicating very high levels. For illustration purposes, we introduce the following percentile-based categorization based on the 2015 governance scores : very good (>90 percentile), good (75 - 90), medium (50 - 74), weak (25 - 49), very weak (<25 percentile). **d-f**, Estimated population living in countries with different governance levels for 2015, 2050 and 2100. Total population size differ as a result of the diverging projections of future population under different SSPs.

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182

183 There is no rule of thumb for which levels of this indicator represent ‘good’ governance. In fact,
184 any such categorization arguably also includes value judgement. For the sake of illustrating the
185 changes over the 21st century, however, we introduce percentile categories based on the 2015
186 distribution of the governance scores (see Figure 2). A clear scenario dependence for projected
187 governance is apparent at a country level (Figure 2a-c). The differences are even more striking
188 when we consider the implications for future populations in countries with different governance
189 regimes (Figure 2d-f). Many countries whose populations are projected to grow substantially are
190 expected to undergo transition and improve their governance over the coming decades, i.e. from
191 “weak” to “medium”, or further. Under the rapid development scenarios such as SSP1 and SSP5,
192 this implies that only a small number of countries will be characterized by very weak or weak
193 governance (defined as the state of a country below the median of the governance indicator
194 today) and almost all countries may reach states of good governance by the end of the century. In
195 contrast, countries that are home to around 3 (5) billion people in 2050 (2100), will continue to be
196 characterized by weak governance under the SSP3 scenario (Figure 2). Even under a middle-of-
197 the-road SSP2 scenario, about 1.5 billion people will be living in about 40 countries characterized
198 by weak governance by mid-century.

199

200 The projection exercise combines short to medium-term dynamic adjustments based on the
201 estimated relationships (and thus extrapolated using the correlation structures found in historical
202 data) with assumption-driven long term developments that ensure the internal consistency of the
203 trajectories with respect to the SSP narratives. Throughout the paper we report results solely for
204 the aggregate governance indicator. However, the projections of the individual dimensions of the
205 indicator can also be used if found to be particularly relevant for the socio-economic issue or a
206 policy objective in focus. Based on our compositional analysis of the governance indicator,
207 adjusted estimates of the effects of socioeconomic developments on particular components of
208 the governance indicator are calculated to provide projections of specific subcomponents such
209 as corruption or governance effectiveness (see Methods and Supplementary Information). This

210 makes our results applicable to a wide range of issues under consideration in policy agendas
211 related to sustainable development and climate actions.

212

213 It is important to highlight that our approach does not imply a direction of causal linkages.
214 Improvements in governance in the context of sustainable development can lead to a virtuous
215 cycle between governance and development, rather than showing a cause-and-effect
216 relationship²⁸. Since the focus of our model is not to unveil the causal effects, but rather to
217 consistently extend the SSPs, such potential mutually re-enforcing dynamics only further
218 underscore the need for an integration of governance into the SSP framework.

219

220 Importance of near-term improvements in governance

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222 In a world with near-term sustainable development targets and ongoing climate change, the
223 temporal evolution of our governance indicators is of particular interest. We find that countries
224 characterized by very weak governance, albeit starting from a low level, have an up to five times

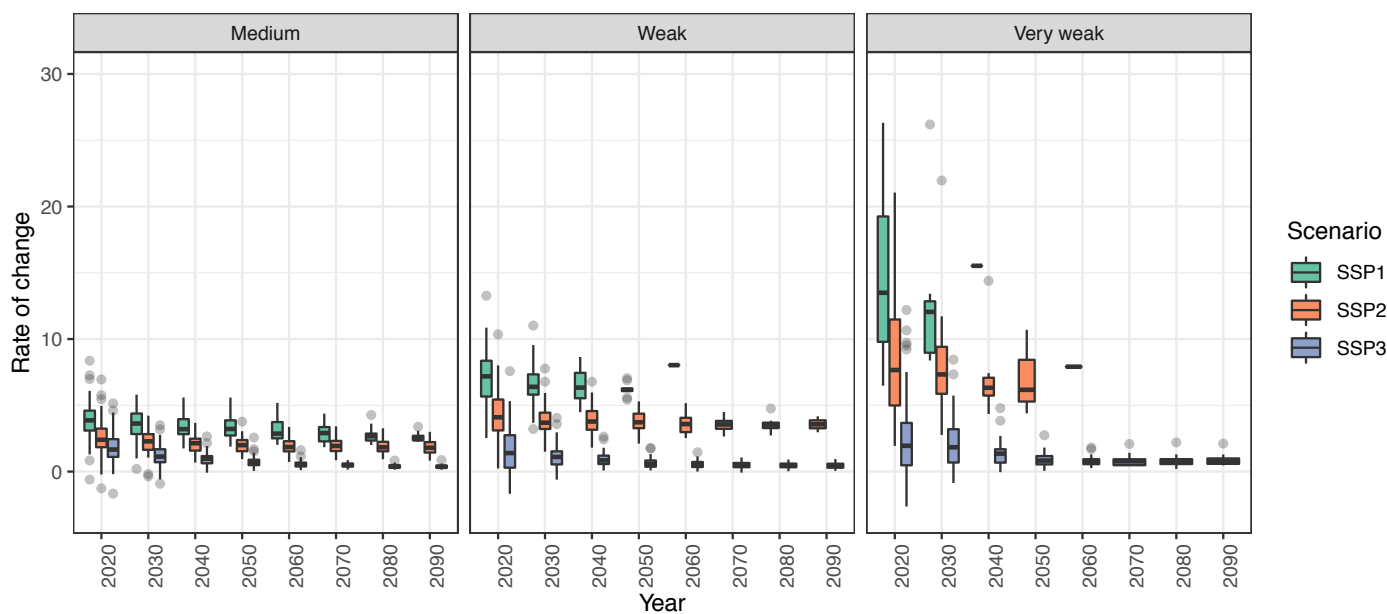


Figure 3: **Rates of change of governance**

Box-Whisker diagram of the five-year rates of change in governance for different SSPs over the 21st century. The lower and upper hinges correspond to the first and third quartiles (the 25th and 75th percentiles). The upper whisker extends from the hinge to the highest value that is within 1.5 * interquartile range of the hinge. Data beyond the end of the whiskers are outliers and plotted as points. Panels separate out the evolution for country groupings classified by their state of governance (time-dependent). For SSP 1, no countries will be in the 'very weak' category after 2030 (2050) following high rates of improvement in governance in the preceding decades. SSP 4 and 5 are omitted from the figure for clarity.

225

226 higher rate of improvement in scenarios of rapid socio-economic development under SSP1 and

227 SSP5 compared to SSP3. The absolute values for countries in the 'medium' category is

228 considerably smaller, although differences between the scenarios are still evident (up to a factor

229 of four between SSP1 and SSP3). Over time, countries move out of the lower categories, and their

230 rates of change reduce as they improve governance. Our analysis suggests a window of

231 opportunity to eradicate lowest levels of governance in the near term. This highlights the

232 importance of achieving the goals under the 2030 Agenda for Sustainable Development to

233 facilitate long-term sustainable development, particularly for the countries characterized by the

234 lowest levels of development to date.

235

236 [Governance and adaptation to climate change](#)

237

238 Adaptation is multi-faceted and sector-dependent. As both the integral part of sustainable
239 development and a stand-alone mechanism in coping with climate change, adaptive capacity is
240 difficult to measure because of the volatile nature of its many determinants. Successful adaptation
241 will depend in part on the timescales of improvement of socio-economic factors many of which
242 are now available in the SSP framework. The existing projections including that of governance
243 can subsequently be used for designing an overarching framework to evaluate more granular and
244 sector-specific measurements of adaptive capacity.

245

246 Across all scales, however, a key determinant is the ability to effectively leverage private and
247 public sector investment for adaptation actions. This is coined “adaptation readiness” in the Notre
248 Dame Global Adaptation Index (ND-GAIN)²⁹, a summary indicator of countries’ vulnerability to
249 climate change. The concept of adaptation readiness can also be seen as an indication for
250 countries’ absorptive capacities of international climate finance channeled, for instance, through
251 the Green Climate Fund³⁰. If the readiness is low, successful adaptation financing and
252 implementation is questionable. Governance is indeed a key ingredient in the ND-GAIN readiness
253 score. Given the high correlation of the readiness score with our governance indicator (0.93, $p =$
254 0.000), our projections thereby allow us to deduce the future trajectories of the ND-GAIN
255 readiness score in line with the different SSP scenarios.

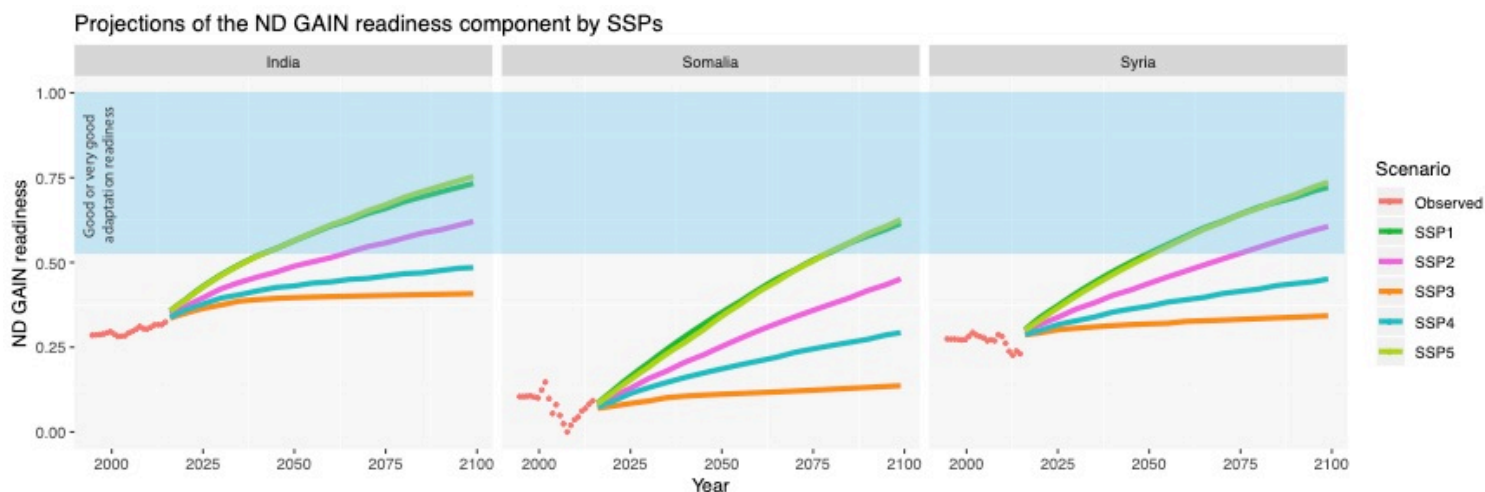


Figure 4: **Projections of the ND GAIN Adaptation Readiness score.** Trajectories for India, Somalia and Syria are shown for different SSPs. The projections of the Adaptation Readiness score are based on our projections of future governance. The shaded region marks the range of the readiness indicator for categories ‘good’ and ‘very good’ in 2015 (0.52-0.80). For global projections see Figures S6 and S7.

256

257 The range of adaptation readiness spanned by the member states of the Organization for
 258 Economic Cooperation and Development (OECD) today match well with our ‘good’ and ‘very
 259 good’ categories. Most developing countries, however, will barely, if at all, reach levels of ‘good’
 260 adaptation readiness by mid-century, even under the optimistic scenarios SSP1 and SSP5 (Figure
 261 4). Under SSP3 and SSP4, little to no improvement in adaptation readiness is apparent, with an
 262 ever increasing number of people living in countries with low adaptive capacity (see Figures 6 and
 263 7 in Supplementary Information). Our results are fully in line with the qualitative classification of
 264 adaptation challenges in the SSP scenarios: low challenges in SSP1 and SSP5; and high
 265 challenges in SSP 3 and SSP4¹⁵. However, we also show that ‘low challenges’ are not equivalent
 266 to ‘no challenges’. Even under SSP 1, adaptive capacity will only increase gradually over the next
 267 decades while an adaptation deficit to present day climate is already apparent³¹. To that end, our
 268 results also illustrate what could be considered an ‘upper limit’ of the future evolution of adaptive
 269 capacity.

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271

272 [Timescales of governance and climate change](#)

273

274 The recent IPCC Special Report on Global Warming of 1.5°C¹ has underscored the substantial
275 differences in climate impacts between 1.5°C and 2°C that could materialize already before mid-
276 century. Tropical regions will be bearing the brunt of these differences³²⁻³⁴ and will also be the
277 regions where the anthropogenic climate change is emerging the fastest against the background
278 of natural variability³⁵. Thereby, while vulnerable countries will be striving for sustainable
279 development and improving their adaptive capacity, climate impacts will continue to intensify. Our
280 results show that even under scenarios of rapid and sustainable development (SSP1 and SSP5),
281 improvements of adaptive capacity will take on average at least three decades. This indicates that
282 (temporal) limits to improvements in adaptive capacity may persist during the 21st century leading
283 to elevated risks and impacts of climate change in countries with low socio-economic
284 development. Climate impacts that exceed the limits to adaptation will result in climate-related
285 loss and damage³⁶⁻³⁸. Given that negative climate impacts can hamper countries' abilities to
286 achieve sustainable development, and thereby improving adaptive capacity, our results indicate
287 that adequate responses and support schemes for loss and damage will be crucial policy
288 instruments to support vulnerable countries³⁹.

289

290 Country-level representation of governance does have several limitations. The methodological
291 framework used for the projection exercise presented in this study can be complemented with
292 methods to downscale global assumptions and estimates. Scenario narratives and local
293 interpretations of the SSPs can be derived from qualitative methods. The analytical methods
294 employed to provide inference on the drivers of institutional change rely on the assumption of a
295 common response of the governance indicators to their determinants across countries.
296 Combining the advantages of a global analytical model of governance dynamics such as the one
297 presented here with those of a narrative based on a qualitative context-specific assessment of
298 future governance changes can improve the quality of our projections further. Such an extension
299 of our analysis appears particularly important for countries for which the existing data are missing
300 or not reliable, as well as for countries where disruptive changes in the current institutional setting
301 are likely in the future. To address the issue of internal inequalities and sub-national specificities,

302 we here have to rely on our indicator's multiple sources and dimensions. An analysis
303 incorporating sub-national information is a promising research avenue. Further unobserved
304 differences between countries are controlled for in our model by using country-specific fixed
305 effects, and global trends by yearly fixed effects.

306

307 The SSP narrative framework by design does not incorporate feedbacks of climate impacts. This
308 is important to keep in mind, particularly in the context of high warming scenarios or in scenarios
309 with persistently low levels of development in some regions of the world. Even under the SSP3
310 scenario, no country is projected to see a decline in socio-economic development. This 'scenario
311 optimism' can stand in stark contrast to the observed dynamics, where in reality some countries
312 such as Syria have experienced rapid decline in stability over the past recent years (Figure 1a).
313 The dynamics behind such deteriorations are difficult to incorporate in deterministic modelling
314 approaches underlying the SSPs, which represents a limitation of scenario frameworks in general.
315 While conflicts are context-dependent and not deterministic, some key determinants of conflict
316 risks can be linked to the SSP pathways and indicate increasing globally increasing conflict risks
317 for SSP3 and SSP4 centered in Central and South Asia as well as Africa⁴⁰. Considering such risks
318 would lead to considerably higher probabilities for a deterioration of governance under those
319 scenarios, thereby painting a more accurate, but even bleaker picture compared to the
320 sustainable development scenarios.

321

322 Uncertainties related to trajectories of future vulnerability have been found to dominate climate
323 impacts in the near term⁴¹, but will also shape the end-of-century climate impacts⁴². Climate-
324 related natural disasters displace millions⁴³ already today, cause multi-billion dollar damages⁴⁴
325 and may even contribute to increased risks of armed conflict outbreaks⁴⁵ and exacerbate forced
326 migration⁴⁶. Projections of future economic impacts of climate change indicate non-linear
327 increases in damages, which are most pronounced for tropical countries⁴⁷. Thereby, integrating
328 climate change impacts into SSP trajectories would affect the global trajectories of socio-
329 economic development, in particular for high emission scenarios. To do so, however, requires an

330 improved understanding of the prospects of future adaptation. The projections of governance and
331 adaptive capacity provided here contribute to closing this gap. Our study thus presents a step
332 forward towards a more integrated scenario perspective to inform global policies aimed at
333 achieving sustainable development.

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- 347 1. IPCC. *Global Warming of 1.5 °C: an IPCC special report on the impacts of global warming of 1.5 °C*
348 *above pre-industrial levels and related global greenhouse gas emission pathways, in the context of*
349 *strengthening the global response to the threat of climate chang.* (2018).
- 350 2. Klein, R. J. T. *et al.* Adaptation opportunities, constraints, and limits. in *Climate Change 2014:*
351 *Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working*
352 *Group II to the Fifth Assessment Report of the Intergovernmental Panel of Climate Change* (eds.
353 Field, C. B. *et al.*) 899–943 (Cambridge University Press, 2014).
- 354 3. Acemoglu, D. & Robinson, J. A. *Why nations fail: The origins of power, prosperity, and poverty.*
355 (Broadway Business, 2013).
- 356 4. Hughes, B. B. *et al.* PATTERNS OF POTENTIAL HUMAN PROGRESS VOLUME 5 STRENGTHENING
357 GOVERNANCE GLOBALLY: FORECASTING THE NEXT 50 YEARS. in *Strengthening Governance*
358 *Globally: Forecasting the Next 50 Years* (Frederick S. Pardee Center for International Futures,
359 University of Denver Published, 2014).
- 360 5. UN General Assembly. *Transforming our world: the 2030 Agenda for Sustainable Development.*
361 (2015).
- 362 6. Eisenack, K. *et al.* Explaining and overcoming barriers to climate change adaptation. *Nat. Clim.*
363 *Chang.* **4**, 867–872 (2014).
- 364 7. Dasgupta, S. & De Cian, E. The influence of institutions, governance, and public opinion on the
365 environment: Synthesized findings from applied econometrics studies. *Energy Res. Soc. Sci.* **43**, 77–
366 95 (2018).
- 367 8. Berrang-Ford, L. *et al.* Tracking global climate change adaptation among governments. *Nat. Clim.*
368 *Chang.* **9**, (2019).
- 369 9. Weiler, F., Klöck, C. & Dornan, M. Vulnerability, good governance, or donor interests? The allocation
370 of aid for climate change adaptation. *World Dev.* **104**, 65–77 (2018).
- 371 10. Lesnikowski, A., Ford, J., Biesbroek, R., Berrang-Ford, L. & Heymann, S. J. National-level progress
372 on adaptation. *Nat. Clim. Chang.* **6**, (2015).
- 373 11. Berrang-Ford, L. *et al.* What drives national adaptation? A global assessment. *Clim. Change* (2014).
374 doi:10.1007/s10584-014-1078-3
- 375 12. Mahmud, T. & Prowse, M. Corruption in cyclone preparedness and relief efforts in coastal
376 Bangladesh: Lessons for climate adaptation? *Glob. Environ. Chang.* **22**, 933–943 (2012).

- 377 13. Mauro, P. Corruption and Growth. *Q. J. Econ.* **110**, 681–712 (1995).
- 378 14. Abed, G. T. *et al.* *Governance, corruption and Economic Performance.* (2002).
- 379 15. O’Neill, B. C. *et al.* The roads ahead: Narratives for shared socioeconomic pathways describing
380 world futures in the 21st century. *Glob. Environ. Chang.* **42**, 169–180 (2017).
- 381 16. Kc, S. & Lutz, W. The human core of the shared socioeconomic pathways: Population scenarios by
382 age, sex and level of education for all countries to 2100. *Glob. Environ. Chang.* (2014).
383 doi:10.1016/j.gloenvcha.2014.06.004
- 384 17. Jiang, L. & O’Neill, B. C. Global urbanization projections for the Shared Socioeconomic Pathways.
385 *Glob. Environ. Chang.* **42**, 193–199 (2017).
- 386 18. Crespo Cuaresma, J. Income projections for climate change research: A framework based on
387 human capital dynamics. *Glob. Environ. Chang.* **42**, 226–236 (2015).
- 388 19. Leimbach, M., Kriegler, E., Roming, N. & Schwanitz, J. Future growth patterns of world regions - A
389 GDP scenario approach. *Glob. Environ. Chang.* **42**, 215–225 (2013).
- 390 20. Dellink, R., Chateau, J., Lanzi, E. & Magné, B. Long-term economic growth projections in the Shared
391 Socioeconomic Pathways. *Glob. Environ. Chang.* **42**, 200–214 (2017).
- 392 21. Crespo Cuaresma, J. & Lutz, W. The demography of human development and climate change
393 vulnerability: A projection exercise. *Vienna Yearb. Popul. Res.* **13**, 241–262 (2016).
- 394 22. Rao, N. D., Sauer, P., Gidden, M. & Riahi, K. Income inequality projections for the Shared
395 Socioeconomic Pathways (SSPs). *Futures* **0**, 1–13 (2018).
- 396 23. Kaufmann, D. The Worldwide Governance Indicators Methodology and Analytical Issues. (2010).
- 397 24. Kaufmann, D., Kraay, A., Mastruzzi, M. & Bank, T. W. *The Worldwide Governance Indicators Project:
398 Answering the Critics.* (2007).
- 399 25. Inglehart, R. & Welzel, C. *Development and Democracy: What We Know about Modernization Today.*
400 (2009).
- 401 26. Epstein, D. L., Bates, R., Goldstone, J., Kristensen, I. & O’Halloran, S. Democratic Transitions. *Am. J.
402 Pol. Sci.* **50**, 551–569 (2006).
- 403 27. Jha, C. K. & Sarangi, S. Women and corruption: What positions must they hold to make a
404 difference? *J. Econ. Behav. Organ.* **151**, 219–233 (2018).
- 405 28. Kraay, A. & Kaufmann, D. *Growth Without Governance.* (The World Bank, 2002). doi:10.1596/1813-
406 9450-2928

- 407 29. Chen, C.; *et al.* *University of Notre Dame Global Adaptation Index Country Index Technical Report*.
408 (2015).
- 409 30. Brechin, S. R. & Espinoza, M. I. A case for further refinement of the Green Climate Fund's 50:50 ratio
410 climate change mitigation and adaptation allocation framework: toward a more targeted approach.
411 *Clim. Change* 1–10 (2017). doi:10.1007/s10584-017-1938-8
- 412 31. Lobell, D. B. & Tebaldi, C. Getting caught with our plants down: the risks of a global crop yield
413 slowdown from climate trends in the next two decades. *Environ. Res. Lett.* **9**, 074003 (2014).
- 414 32. Schleussner, C.-F. *et al.* Differential climate impacts for policy relevant limits to global warming: the
415 case of 1.5°C and 2°C. *Earth Syst. Dyn.* **7**, 327–351 (2016).
- 416 33. King, A. D. & Harrington, L. J. The Inequality of Climate Change From 1.5 to 2°C of Global Warming.
417 *Geophys. Res. Lett.* **45**, 5030–5033 (2018).
- 418 34. Schleussner, C.-F. *et al.* 1.5°C Hotspots: Climate Hazards, Vulnerabilities, and Impacts. *Annu. Rev.*
419 *Environ. Resour.* **43**, 135–163 (2018).
- 420 35. King, A. D. *et al.* Emergence of heat extremes attributable to anthropogenic influences. *Geophys.*
421 *Res. Lett.* n/a-n/a (2016). doi:10.1002/2015GL067448
- 422 36. Mace, M. J. & Verheyen, R. Loss, Damage and Responsibility after COP21: All Options Open for the
423 Paris Agreement. *Rev. Eur. Comp. Int. Environ. Law* **25**, 197–214 (2016).
- 424 37. Serdeczny, O. Non-economic losses and the Warsaw International Mechanism. in *Loss and Damage*
425 *from Climate Change. Concepts, Principles and Policy Options* (eds. Mechler, R., Bouwer, L. M.,
426 Linnerooth-Bayer, J., Schinko, T. & Surminski, S.)
- 427 38. James, R. *et al.* Characterizing loss and damage from climate change. *Nat. Clim. Chang.* **4**, 2014–
428 2016 (2015).
- 429 39. Thomas, A. & Benjamin, L. Management of loss and damage in small island developing states:
430 implications for a 1.5 °C or warmer world. *Reg. Environ. Chang.* 1–10 (2017). doi:10.1007/s10113-
431 017-1184-7
- 432 40. Hegre, H. *et al.* Forecasting civil conflict along the shared socioeconomic pathways. *Environ. Res.*
433 *Lett.* **11**, 054002 (2016).
- 434 41. Hallegatte, S. *et al.* *Shock Waves: Managing the impacts of climate change on Poverty*. (World Bank
435 Publications, 2015).
- 436 42. Hinkel, J., Vuuren, D. P., Nicholls, R. J. & Klein, R. J. T. The effects of adaptation and mitigation on

- 437 coastal flood impacts during the 21st century. An application of the DIVA and IMAGE models. *Clim.*
438 *Change* **117**, 783–794 (2012).
- 439 43. Heslin, A., Deckard, N. D., Oakes, R. & Montero-Colbert, A. Displacement and resettlement:
440 understanding the role of climate change in contemporary migration. in *Loss and Damage from*
441 *Climate Change* 237–258 (Springer, 2019).
- 442 44. Munich Re. NatCatService. (2018). Available at: <http://natcatservice.munichre.com/>. (Accessed: 24th
443 January 2018)
- 444 45. Schleussner, C., Donges, J. F., Donner, R. V & Joachim, H. Armed-conflict risks enhanced by
445 climate-related disasters in ethnically fractionalized countries. 1–6 (2016).
446 doi:10.1073/pnas.1601611113
- 447 46. Abel, G. J., Brottrager, M., Crespo Cuaresma, J. & Muttarak, R. Climate, conflict and forced
448 migration. *Glob. Environ. Chang.* **54**, 239–249 (2019).
- 449 47. Burke, M., Hsiang, S. M. & Miguel, E. Global non-linear effect of temperature on economic
450 production. *Nature* **527**, 235–239 (2015).
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- 452

453 **Methods**

454

455 Data

456

457 We use the Worldwide Governance Indicators (WGI) database, that provides a composite governance index
458 based six categories: voice and accountability, political stability, government effectiveness, regulatory
459 quality, rule of law and control of corruption. After standardizing the indicator from its original -2.5 to 2.5
460 range to the range from 0 to 1, our main response variable was the arithmetic average of the six
461 components, referred to as the governance indicator throughout the paper. Historical GDP per capita is
462 taken from the Penn World Table 7.0¹ and SSP projections from Crespo Cuaresma². Measures of education
463 (share of population with post-secondary education) and gender equality in education (difference in mean
464 years of schooling between men and women) come from the Wittgenstein Centre for Demography and
465 Global Human Capital³.

466

467 Model

468

469 The estimation of the effects of the covariates mentioned above on the governance indicator was carried
470 out using a yearly country-level panel data spanning the period between 1995 and 2015. Our main
471 specification is as follows:

472

473
$$governance_{i,t} = \beta_1 \ln(GDPpc)_{i,t} + \beta_2 education_{i,t} + \beta_3 gendergap_{i,t} + \alpha_i + \gamma_t + \varepsilon_{i,t} \quad (1)$$

474

475 where α_i controls for time-invariant country-specific characteristics, and γ_t accounts for common shocks in
476 the sample in the form of year-fixed effects. Including fixed effects allows for the presence of omitted
477 factors and long term trends that might affect both sides of the equation, therefore eliminating bias that
478 might arise from cross-sectional analyses. We provide additional specifications in the Supplementary
479 Information (Table 1), and show that our results are robust for within and between-country regressions
480 underscoring the robustness of our findings also in the light of cross-national differences.

481

482 We project the data forward to the year 2100 by using the coefficient estimates of the model given by
483 equation (1) and imposing them over the internally consistent projections of GDP, education and gender
484 gap in education which is given by the set of existing SSP projections. To remain consistent with the
485 narratives, we account for the unobserved characteristics captured by the country fixed effects, which go
486 beyond what can be explained with changes in governance and are likely to capture further intangible
487 characteristics such as culture, by assuming that they will change over the long course of the projection
488 period. In other words, we calculate rates of convergence between countries in line with the narratives
489 which assume different degrees of reduction of inequality in various socio-economic characteristics: in SSP
490 1, all countries converge in 2130 to the 75th percentile of the present-day distribution, for SSP2 in 2250,
491 SSP3 assumes no convergence at all, for SSP4 in 2250, and SSP5 in 2180.

492

493 Compositional analysis

494

495 The composite nature of our dependent variable (voice and accountability, political stability, government
496 effectiveness, regulatory quality, rule of law, control of corruption) allows for the investigation of whether
497 some of the dimensions stand out in their relationship with the covariates. We treated our governance
498 variable with an isometric-log transformation⁴, and subsequently regressed it against our covariates. This
499 process yields weights within each covariate that relate to each of the dimensions of the governance index,
500 thereby disentangling the extent to which each of the covariates relates to the components of the
501 governance indicator.

502

503 In our analysis of the composite Worldwide Governance Index (comprising six dimension of governance),
504 we find a distinct relationship between post-secondary education and two dimensions of the dependent
505 variable: control of corruption and government effectiveness (see Figure 1 in Supplementary Material). This
506 effect is not surprising and presents additional evidence concerning the importance of education (post-
507 secondary education) for better institutions and demand for eradication of corruption⁵. Based on this
508 finding, we separately project indicators of corruption and government effectiveness, thereby capturing the
509 effect of different rate of change of educational expansion across the scenarios (see Figures 2-5 in
510 Supplementary Information).

511

512

513

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518 **Author contributions** The research was designed by MA, JCC and CFS. MA performed the analysis and
519 created the display items. All authors contributed to the writing of the manuscript.

520 **Competing interests** The authors declare no competing interests.

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522 **Code availability:** Code underlying the results is available at [https://github.com/marina-](https://github.com/marina-andrijevic/governance2019)
523 [andrijevic/governance2019](https://github.com/marina-andrijevic/governance2019)

524 **Data availability:** Governance data is available on the Worldwide Governance Indicators website
525 (<https://info.worldbank.org/governance/wgi/#home>) . Historical GDP was obtained from the Penn World
526 Tables 7.0 (<https://www.rug.nl/ggdc/productivity/pwt/pwt-releases/pwt-7.0>) and projected values through
527 the IIASA SSP database (<https://tntcat.iiasa.ac.at/SspDb/>). Data on educational attainment and gender
528 equality in education is accessible through the Data Explorer of the Wittgenstein Centre for Demography
529 and Global Human Capital (<http://dataexplorer.wittgensteincentre.org/wcde-v2/>).

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- 531 1. Heston, A., Summers, R. & Aten, B. *Penn World Table 7.0*. (2011).
- 532 2. Crespo Cuaresma, J. Income projections for climate change research: A framework based on
533 human capital dynamics. *Glob. Environ. Chang.* **42**, 226–236 (2015).
- 534 3. Wittgenstein Centre for Demography and Global Human Capital. Wittgenstein Centre Human Capital
535 Data Explorer Version 2.0. (2018). Available at: <http://dataexplorer.wittgensteincentre.org/wcde-v2/>.
536 (Accessed: 14th April 2019)
- 537 4. van den Boogaart, K. G. & Tolosana-Delgado, R. Fundamental Concepts of Compositional Data
538 Analysis. in *Analyzing Compositional Data with R* 13–50 (Springer Berlin Heidelberg, 2013).
539 doi:10.1007/978-3-642-36809-7_2
- 540 5. Lutz, W., Cuaresma, J. C. & Abbasi-Shavazi, M. J. Demography, Education, and Democracy: Global
541 Trends and the Case of Iran. *Popul. Dev. Rev.* **36**, 253–281 (2010).

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