

Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Portfolio policies, see our [Editorial Policies](#) and the [Editorial Policy Checklist](#).

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a Confirmed

- | | | |
|-------------------------------------|-------------------------------------|--|
| ☐ | ☒ | The exact sample size (n) for each experimental group/condition, given as a discrete number and unit of measurement |
| ☒ | ☐ | A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly |
| ☒ | ☐ | The statistical test(s) used AND whether they are one- or two-sided
<i>Only common tests should be described solely by name; describe more complex techniques in the Methods section.</i> |
| ☒ | ☐ | A description of all covariates tested |
| ☒ | ☐ | A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons |
| ☐ | ☒ | A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals) |
| ☒ | ☐ | For null hypothesis testing, the test statistic (e.g. F , t , r) with confidence intervals, effect sizes, degrees of freedom and P value noted
<i>Give P values as exact values whenever suitable.</i> |
| ☒ | ☐ | For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings |
| ☒ | ☐ | For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes |
| ☒ | ☐ | Estimates of effect sizes (e.g. Cohen's d , Pearson's r), indicating how they were calculated |

Our web collection on [statistics for biologists](#) contains articles on many of the points above.

Software and code

Policy information about [availability of computer code](#)

Data collection	Projections on future emissions were performed using Python and Global Change Assessment Model (v 5.4). Projections on future baseline mortality rates were retrieved using the International Futures (v 7.64) software. Earth System Model version 4.1 (ESM4.1) were used to validate the TM5-FASST source receptor matrices. No other software was used to collect the data.
Data analysis	Python (v3.6) and R(v3.6) was used for data analysis.

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio [guidelines for submitting code & software](#) for further information.

Data

Policy information about [availability of data](#)

All manuscripts must include a [data availability statement](#). This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our [policy](#)

All the data being used in this study are publicly available, which can be downloaded from the links below:

Relative risks: <https://ghdx.healthdata.org/record/ihme-data/gbd-2019-relative-risks>

Projections on future baseline mortality rates of cardiovascular diseases, diabetes, malignant neoplasm, infectious respiratory diseases, and non-infectious respiratory diseases are from International Futures (v7.64): <https://korbel.du.edu/pardee/international-futures-platform/download-ifs>
 Projections on future death rates of chronic obstructive pulmonary disease (COPD), diabetes mellitus type II (DB), ischemic heart disease (IHD), lung cancer (LC), lower respiratory infections (LRI), and stroke; cardiovascular diseases, diabetes, malignant neoplasm, infectious respiratory diseases, and non-infectious respiratory diseases, are from Global Health Data Exchange (GHDx): <https://vizhub.healthdata.org/gbd-results/>
 Source-receptor matrices of TM5-FASST model: <https://tm5-fasst.jrc.ec.europa.eu>
 Emissions Database for Global Atmospheric Research (EDGAR): https://edgar.jrc.ec.europa.eu/dataset_ghg50

Human research participants

Policy information about [studies involving human research participants and Sex and Gender in Research.](#)

Reporting on sex and gender

n/a

Population characteristics

n/a

Recruitment

n/a

Ethics oversight

n/a

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences

☐ Behavioural & social sciences

☒ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see [nature.com/documents/nr-reporting-summary-flat.pdf](https://www.nature.com/documents/nr-reporting-summary-flat.pdf)

Ecological, evolutionary & environmental sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description

In this study, we construct a large-scale scenario ensemble using a process-based modeling framework to assess the air quality and health equity impacts of carbon pricing,

Research sample

We sampled nearly 30,000 scenarios using GCAM modeling, each with an air quality and health assessment. All the data and model codes being used in this study are publicly available, which can be downloaded from the links below:
 -GCAM 5.4 model: <https://github.com/JGCRI/gcam-core/releases>
 -Relative risks: <https://ghdx.healthdata.org/record/ihme-data/gbd-2019-relative-risks>
 -Projections on future baseline mortality rates of cardiovascular diseases, diabetes, malignant neoplasm, infectious respiratory diseases, and non-infectious respiratory diseases are from International Futures (v7.64): <https://korbel.du.edu/pardee/international-futures-platform/download-ifs>
 -Projections on future death rates of chronic obstructive pulmonary disease (COPD), diabetes mellitus type II (DB), ischemic heart disease (IHD), lung cancer (LC), lower respiratory infections (LRI), and stroke; cardiovascular diseases, diabetes, malignant neoplasm, infectious respiratory diseases, and non-infectious respiratory diseases, are from Global Health Data Exchange (GHDx): <https://vizhub.healthdata.org/gbd-results/>
 Source-receptor matrices of TM5-FASST model: <https://tm5-fasst.jrc.ec.europa.eu>

Sampling strategy

We construct a large-scale scenario ensemble using GCAM v5.4. We consider one policy lever, i.e., whether a globally uniform carbon price trajectory is implemented from 2020-2100. We then sample seven types of future uncertainties in socioeconomic, technological, and land-use aspects. We deploy a full factorial experimental design across the seven factors to encompass a wide range of futures. Among the seven, four of them (i.e., socioeconomic, energy demand, agricultural and land use, fossil fuel extraction costs) are sampled by considering five sets of assumptions that reflect the storylines of Shared Socioeconomic Pathways (SSPs). For the other three factors, we sample the future water runoffs using varying levels of groundwater level and reservoir capacity, and we sample the future competitiveness of low-emission energy technologies and carbon capture and sequestration (CCS) technology using varying levels of projected costs. The quantitative assumptions for different SSPs and technology costs are reported in Lamontagne et al. 2018 (<https://doi.org/10.1002/2017EF000701>) and Calvin et al. 2017 (<https://doi.org/10.1016/j.gloenvcha.2016.06.010>). The total number of scenarios is 2 (carbon policies) x 4 (water runoffs) x 5 (socioeconomics) x 5 (energy demand) x 5 (agriculture and land use) x 5 (fossil fuel costs) x 3 (low-emissions energy costs) x 2 (CCS costs) = 30,000.

Data collection

Data collection in this study involved downloading publicly available datasets from the websites, running queries to collect GCAM scenarios results, and generating future baseline mortality rate using the International Futures software. All data were collected by Xinyuan Huang, except for GCAM scenario results were collected by Vivek Srikrishnan and Xinyuan Huang together.

Timing and spatial scale

n/a

Data exclusions	<input type="text" value="No data were excluded from the analysis."/>
Reproducibility	<input type="text" value="To verify the data reproducibility, we produced scripts to run the datasets in batch so as to ensure the data for each scenario/year are processed in the exact same way."/>
Randomization	<input type="text" value="n/a"/>
Blinding	<input type="text" value="n/a"/>

Did the study involve field work? ☐ Yes ☒ No

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☒	☐ Palaeontology and archaeology
☒	☐ Animals and other organisms
☒	☐ Clinical data
☒	☐ Dual use research of concern

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging