Replication package for "An Analytical Framework to Price Long-Dated Climate-Exposed Assets"

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Overview

This repository contains the code necessary to replicate the results of the paper titled "An Analytical Framework to Price Long-Dated Climate-Exposed Assets."

Requirements

The analysis published in the paper has been conducted using R version 4.3.1 (2023-06-16) – "Beagle Scouts."

Instructions to Replicators

To replicate the results, execute the script `main.R`. - The script begins by calibrating `mu_T` using the bisection method, which takes approximately 30 seconds. - Within `main.R`, the replciator has the option to generate specific tables and figures, with detailed instructions included as commented code. By default, the code produces all the figures and tables in the paper. - On line 26 of `main.R`, the replicator may want to modify the variable `number.of.cores`, which specifies the number of cores to use for parallel computing. Parallel processing is employed to generate certain figures that require multiple model runs, such as sensitivity analyses. By default, `number.of.cores` is set to 8. If the computer of the replcicator has fewer than 8 cores, the maximum available number of cores will be used.

Libraries

Ensure that all necessary libraries referenced in `main.R` are installed prior to running the code. Libraries needed: parallel, doParallel, mgcv, colorspace, broman, optimx, MASS, expm.

Runtime and Storage Requirements

- On a setup with a 2.3 GHz 8-Core Intel Core i9 processor, all figures and tables (including those in the supplemental materials) can be generated in about 15 minutes. Depending on the setup, approximate time needed to reproduce the analyses on a standard (2025) desktop machine: 10-30 minutes
- Approximate storage space needed: < 5 MBytes

Controlled Randomness

Random seed is set:

- at line 9 of program make_figure_gamma0_distri.R. This script produces the figure illustrating the gamma0 distribution (Figure 9).
- within function `compute.SCC.Lemoine`; this function utilizes Lemoine (2021) model to compute yields and Social Cost of Carbons (SCC). It is included in the script `procedures/functions_other_models.R`. It is used in `outputs/make_figures/make_figure_YC_RF.R` to produce Figure 6 (yield curves) and Figure S.4 (Term structure of temperature risk premiums).
- The other results of the paper are not based on pseudo-random number generators.

Directory Structure

The repository is organized into several folders, detailed as follows:

1. **data/**: Contains data files used for calibration and plotting.
2. **estimations/**: Contains R scripts for estimating and calibrating the model.
3. **outputs/**: Includes scripts for producing figures and tables, along with the generated outputs (see table below).
4. **procedures/**: Contains various procedures used to solve the model, price assets, and generate outputs.

The main directory includes **main.R**, that is the primary script to source for replicating the paper's results.

List of Tables and Figures Produced by the Codes

The provided code reproduces the tables and figures in the paper, including those in the supplemental appendix. The exception is Figure 1, which is a schema created using the TikZ package in LaTeX. Tables 3, 4, and 6 are also exceptions; they contain formulas written directly in LaTeX.

All scripts used to generate figures are located in the folder `outputs/make_figures/`. All scripts for producing tables are in `outputs/make_tables/`. The resulting figures are saved in PDF format within the folder `outputs/Figures/`, and all tables are written in LaTeX and stored as `.txt` files in `outputs/Tables/`.

Figure/Table #	Program	Output file
Figure 2	`make_figure_IRF1Gt.R`	`Figure_IRF1GtC.pdf`
Figure 3	`make_figure_Damage_comparison.R`	`Figure_Damage_comparison.pdf`
Figure 4	`make_figure_Tpdf.R`	`Figure_Tat_P_and_Q_vector_CI.pdf`
Figure 5	`make_figure_Hpdf.R`	`Figure_SL_P_and_Q_vector_CI.pdf`
Figure 6	`make_figure_YC_RF.R`	`Figure_YC_RF.pdf`
Figure 7	`make_figure_breakeveninflation.R`	`Figure_BreakEvenInflation.pdf`
Figure 8	`make_figure_options.R`	`Figure_Option_Digital.pdf`
Figure 9	`make_figure_gamma0_distri.R`	`Figure_gamma0.pdf`
Figure 10	`make_figure_gamma0_distri.R`	`Figure_gamma0_Damages.pdf`
Figure 11	`make_figure_RCP_to_TAT.R`	`Figure_RCP_to_TAT.pdf`
Figure S.1	`make_figure_calibration.R`	`Figure_Calibration.pdf`
Figure S.2	`make_figure_mu.R`	`FFigure_Mitigation_comparison.pdf`
Figure S.3	`make_figure_RCP_to_TAT.R`	`Figure_SCCvsTRP.pdf`
Figure S.4	`make_figure_YC_RF.R`	`Figure_TRP_comparison.pdf`
Figure S.5	`make_figure_Merton.R`	`Figure_Merton2.pdf`
Table 1	`make_table_Estimated_Param.R`	`table_param_est.txt`
Table 2	`make_table_utility_solution.R`	`table_utility_solution.txt`
Table 5	`make_table_SCC.R`	`table_SCC_sensitiv.txt`
Table 7	`make_table_param.R`	`table_param.txt`
Table S.1	`make_table_SCC.R`	`table_TRP_sensitiv.txt`
Table S.2	`make_table_SCC.R`	`table_LTR_sensitiv.txt`

Data Availability and Provenance Statements

Statement about Rights

We certify that the authors of the manuscript have legitimate access to and permission to use the data included in this manuscript. We also certify that the authors have permission to redistribute and publish the data contained within this replication package. Details are provided below. The remaining code (beyond the data mentioned above) is licensed by the authors under the CC-BY-NC 4.0 Unported license. Further redistribution and use must adhere to the relevant license terms. Relevant permissions are documented in the LICENSE.txt file.

Some data used to construct Figure 2 are obtained from the USEPA/scghg repository, which provides code to replicate EPA (2023) results. These data are provided under the MIT License, allowing free use, modification, and distribution. We gratefully acknowledge Bryan Parthum for his support in helping us access and work with this data.

- Some data in the EPA repository (mentioned above) are outputs generated from HECTOR, an open-source model licensed under the GPL v3.0. These outputs are used in Figure 2 and are subject to the terms of that license. Users should review GPL v3.0 to understand their rights and obligations.

- Some data from the EPA repository are outputs generated from the [FaIR (Finite-amplitude Impulse-Response)] model, licensed under the Apache License, Version 2.0. These outputs, used in Figure 2, are governed by that license, which permits use, modification, and distribution according to its terms.

The present package also includes outputs generated with the MAGICC6.0 model, originating from Christian Traeger´s publicly available replication repository (link), associated with Traeger (2023). The author of that package certifies he has legitimate access and permission to publish these data, which are governed by the CC-BY-NC-SA 3.0 Unported license. We used the MATLAB codes in Traeger´s package (also licensed under CC-BY-NC 4.0) to load and process these data.

In our Figure 2, the line labeled "ACE-Joos" is based on data extracted from Christian Traeger´s repository, which utilizes inputs originally obtained from Joos et al. (2013); the latter work is licensed under CC BY 3.0.

Some data in this package originate from the replication package of Bauer and Rudebusch (2023), and are licensed under the CC0 1.0 Universal Public Domain Dedication. These data, used to produce Figure 6, were obtained from Michael Bauer´s personal website and are used here in accordance with the license.

One csv file includes data derived from an Excel file created by William Nordhaus and Lint Barrage. (It is used in Figure S.2 of the Supplemental Appendix; the series is indicated by "DICE2023".) The data and associated program are © DICE2023-Excel-b-4-3-10-v18.3, with copyrights held by William Nordhaus and Lint Barrage. The owners provide free and open access to the program. Commercial users must obtain permission for use in its original form or with changes from the copyright holder.

Details on each Data Source

All data files (listed in the following table) can be found in the `~/data/` folder.

Data.Name	Data.Files	Citation
Social Discount Rates	`Bauer_Rudebusch_sdrs.csv`	Bauer and Rudebusch (2023)
IRF from EPA report	`Figure223_EPA_data.Rdat`	Environmental Protection Agency (2023)
IRF from ACE	`IRF_Traeger_5y.csv`	Traeger (2023)
RCPs based on ACE model	`RCP_Mat_ACE.csv`	Traeger (2023)
RCPs based on MAGICC6.0 model	`RCP_Mat_MAGICC.csv`	Meinshausen et al. (2011), Traeger (2023)
DICE mitigation path	`mu_DICE.csv`	DICE2023; Barrage and Nordhaus (2024)

Details on creation of intermediary files

The two CSV files `RCP_Mat_ACE.csv` and `RCP_Mat_MAGICC.csv` were created by appending the following lines to the end of the script `TempFitSim_ACE.m`, available in Traeger´s (2023) replication package. Running this script in MATLAB generates the CSV files and saves them in the current directory.

```
M_AT = [MagiccOcean.RCP3PD.Carboncycle(:,5) ...
    MagiccOcean.RCP45.Carboncycle(:,5) ...
    MagiccOcean.RCP6.Carboncycle(:,5) ...
    MagiccOcean.RCP85.Carboncycle(:,5)];
```

```
T_AT = [MagiccOcean.RCP3PD.Tempatm ...
    MagiccOcean.RCP45.Tempatm ...
    MagiccOcean.RCP6.Tempatm ...
    MagiccOcean.RCP85.Tempatm];

E_CO2 = [MagiccOcean.RCP3PD.EmissionCO2(:,1) + MagiccOcean.RCP3PD.EmissionCO2(:,2) ...
    MagiccOcean.RCP45.EmissionCO2(:,1) + MagiccOcean.RCP45.EmissionCO2(:,2) ...
    MagiccOcean.RCP6.EmissionCO2(:,1) + MagiccOcean.RCP6.EmissionCO2(:,2) ...
    MagiccOcean.RCP85.EmissionCO2(:,1) + MagiccOcean.RCP85.EmissionCO2(:,2)];

RF = [MagiccOcean.RCP3PD.RFtot ...
    MagiccOcean.RCP45.RFtot ...
    MagiccOcean.RCP6.RFtot ...
    MagiccOcean.RCP85.RFtot];

M = [MagiccOcean.RCP3PD.Year M_AT T_AT E_CO2 RF];
csvwrite('RCP_Mat_MAGICC.csv', M);

M = [(Startdate:timestep:Enddate)' Temp_combined_plot_atm_sim(:,[1 3 5 6])];
csvwrite('RCP_Mat_ACE.csv', M);
```

The file `IRF_Traeger_5y.csv` was created by adding the following line to the end of the script `ImpulseResponseComplot_ACE.m` in Traeger´s (2023) replication package. Running this script in MATLAB generates the CSV file and saves it in the current directory.

```
csvwrite("IRF_Traeger_5y.csv",[ACE_Impulse_DICE5' ACE_Impulse_Joos5']);
```

The `.Rdat` file `Figure223_EPA_data.Rdat` was generated by adding the following line to the end of the script `plot_temperature_anoml.R`, available in the replication package of Tan et al. (2024) at https://github.com/bryanparthum/schfc-paper/tree/main. (Specifically, this R script is available here.)

The code line to add is:

```
save(fair, hector, magicc, file="Figure223_EPA_data.Rdat")
```

The file `mu_DICE.csv` contains the trajectory of emission control rates extracted from the Excel file with outputs of the DICE2023 model. This Excel file is part of the supplementary material associated with Barrage and Nordhaus (2024). It can be accessed directly via this link. The extracted series of emission control rates is located in row 71 of this Excel file, within the worksheet named `Opt`.

References

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