"On the Optimal Design of a Financial Stability Fund"

Replication Package

Árpád Ábrahám* Eva Carceles-Poveda† Yan Liu‡ Ramon Marimon§

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Contents

*University of Bristol
†Stony Brook University
‡Sun Yat-sen University
§Barcelona School of Economics, CREi, European University Institute, CEPR and NBER

Overview

This document describes the replication package for the paper of "On the Optimal Design of a Financial Stability Fund" published in the *Review of Economic Studies*.

Section 1 describes the data files and MATLAB codes calculating sample moments to be used for the calibration of the model. Section 2 explains the MATLAB codes for estimating the Markov regime switching (MRS) process for the productivity, and the MATLAB codes for discretizing an MRS process. Section 3 explains the structure and options of the FORTRAN code for solving the IMD economy. Section 4 explains the MATLAB codes for solving Fund economy. Section 5 explains the policy function plotting codes. Section 6 explains the structure and options of the MATLAB simulation codes used for both the calibration and the quantitative analyses of the model economies. Lastly, Section 7 describes the MATLAB codes for welfare comparison and decomposition.

Table 1 collects the overall structure of the directories which contain relevant data and program files described in each section.

Table 1: Overall structure of the directories of the replication package

Directory	Sub-directory	Section and summary
`Estimation/`		Section 1–2: MATLAB codes for data processing, moments calculation, productivity estimation & discretization, and data moments files
	`data/`	Raw data files
	`discretization/`	Discretized productivity processes
	`estimation results/`	Estimation results for productivity processes
	`figures/`	Figures for productivity series and estimations
	`notes/`	Notes for data measurement, estimation, etc.
	`productivity/`	Measurements for different productivity processes
`Solution/`		Section 3–7: FORTRAN and MATLAB codes for IMD and Fund solutions, policy plotting, simulation, welfare evaluations, and model solutions & moments files
	`.vs/` and `Debug/`	Directories for FORTRAN compilation
	`figures/`	Simulation results
	`IM#/`	Solution files for the IM economy indexed by `#`, used for welfare calculations

Software and Computational Requirements

All codes are written in either MATLAB or FORTRAN . The MATLAB codes are compatible with MATLAB R2022a. The FORTRAN environment is explained in Section 3.

Except for the MATLAB Fund solution code, all the MATLAB codes run efficiently on a laptop of Intel I7 CPU with 16 GB memory. For the Fund solution code and the FORTRAN IMD solution code, we typically use a work station with Intel I9 CPU and 128 GB memory. However, these two

codes can also run on a laptop with Intel I7 or I9 CPU in a reasonable amount of time.

Data Availability Statement

- Except for the spot/forward exchange rates and debt maturity data, all raw data used in the paper are in public domain and downloaded from AMECO database in 2017,[1] and the current database link is as follows:
  - https://economy-finance.ec.europa.eu/economic-research-and-databases/economic-databases/ameco-database_en
- The spot/forward exchange rates data are retrieved from Thomson Reuters' Datastream, accessed through the data subscription of European University Institute in 2017.
- Debt maturity data are from 3 sources:
  - ESM data, which covers debt maturity mostly from mid 1990 to 2015, are obtained through private correspondence with Aitor Erce from ESM on February 13, 2017. The original data are not publicly available, nonetheless the data file for the GIPS countries are included in the replication package.
  - Eurostat data, which covers debt maturity over 2014–2015, are publicly available and can be accessed in the following link https://ec.europa.eu/eurostat/web/main/data/database.
  - OECD dataset (Central Government Debt), with the maturity data series (average term to maturity for total debt) stopped at 2010. The original data are obtained in 2015 from http://stats.oecd.org/Index.aspx, yet they are no longer available from the current OECD Data Explorer https://data-explorer.oecd.org/ (confirmed in July, 2025).

Summary of Figures and Tables in the Paper

Table 2 summarizes the source codes for producing the figures and tables reported in the paper.

Replication Guidance

There is a replication notice at the end of each section or subsection below, providing information on how to run the MATLAB and FORTRAN codes in both `Estimation/` and `Solution/` directory to obtain results listed in Table 2.

[1] AMECO is the annual macro-economic database of the European Commission's Directorate General for Economic and Financial Affairs.

Table 2: Source codes for the figures and tables in the paper

	Replication package	
Results in the paper	Source files	Source codes
Figure 1: Steady state	Solution/figures/ plc_ergodic_MH.pdf	Solution/ policiesplot_MH.m
Figure 2: Fund solution	Solution/figures/ plc6_MH_x_m.pdf	Solution/ policiesplot_MH.m
Figure 3: Path simulation, real variables	Solution/figures/ long2SIMD_MH_1.pdf	Solution/ simulations.m
Figure 4: Path simulation, financial variables	Solution/figures/ long2SIMD_MH_2.pdf	Solution/ simulations.m
Figure 5: Counterfactual simulation, real variables	Solution/figures/ counter2SIMD_MH_1.pdf	Solution/ simulations.m
Figure 6: Counterfactual simulation, financial variables	Solution/figures/ counter2SIMD_MH_2.pdf	Solution/ simulations.m
Figure 7: Default wave	Solution/figures/ counterIMD_MH_1d.pdf	Solution/ simulations.m
Figure C.1: Regime probabilities	Estimation/figures/psY dlogALN-GIPS0012009.pdf	Estimation/panelMRS.m
Table 1: Parameters	Solution/IMD_MH statistics.txt	Solution/ simulation_MH.m
Table 2: Productivity process	Estimation/estimation results/Results dlogALN-GIPS0012009-50000.txt	Estimation/ panelMRS_GS.m
Table 3: Calibration	Estimation/datamoments.txt, Solution/ IMD_MH statistics	Estimation/ momentsGIPS.m, Solution/ simulations.m
Table 4: Welfare gains	Solution/welfare _conditional_MH.txt	Solution/welfare.m
Table 5: Welfare decomposition	Solution/IM1/welfare _decomposition_MH_1.txt, Solution/IM4/welfare _decomposition_MH_4.txt	Solution/welfare.m
Table 6: Statistics at the onset of the crisis	Direct calculation	N.A.

1 Data Sources and Sample Moments

The parental directory for this section is `Estimation/`. Table 3 summarizes the relevant sub-directories and files for the data, data processing, and sample moments calculation.

Table 3: Directories and files for data and sample moments

Parental directory: `Estimation/`		
Directory/files	Files	Explanation
`Acompute.m`		Productivity computation
`momentsGIPS.m`		Moments for GIPS countries
`momentsNG.m`		Moments for non-GIPS countries*
`hpfilter.m`		HP-filter, MATLAB function
`data/`	`AMECO_countrycode.txt`	GIPS: Country code
	`AMECO_GDP.txt`	GIPS: Ouput
	`AMECO_C.txt`	GIPS: Consumption
	`AMECO_G.txt`	GIPS: Government consumption
	`AMECO_Totalhours.txt`	GIPS: Total working hours
	`AMECO_AveHours.txt`	GIPS: Average working hours
	`AMECO_Employment.txt`	GIPS: Employment
	`AMECO_PS.txt`	GIPS: Primary surplus, *constructed***
	`AMECO_PSG.txt`	GIPS: Primary surplus, EDP†
	`AMECO_B.txt`	GIPS: Debt/GDP
	`AMECO_Yield.txt`	GIPS: LTB yield‡
	`AMECO_Coupon.txt`	GIPS: LTB coupon rate
	`AMECO_GDPDeflator.txt`	GIPS: GDP Deflator
	`AMECO_CPI.txt`	GIPS: CPI
	`AMECO_Laborshare.txt`	GIPS: Labor income share
	`AMECO_Investment.txt`	GIPS: Investment
	`AMECO_Humancapital.txt`	GIPS: Human capital
	`Spread_FR.txt`	GIPS: LTB spread over German bond
	`AMECO_GDP_EANP.txt`	non GIPS: GDP
	`AMECO_GDP_PS.txt`	non GIPS: Primary surplus, *constructed***
	`AMECO_GDP_PSG.txt`	non GIPS: Primary surplus, EDP†
`/productivity`	`ALN.txt`§	GIPS: Labor productivity, level
	`dlogALN.txt`	GIPS: Labor productivity, log, detrend

* Within Euro Area

** Constructed to be model consistent; see Section 1.1

† Excessive Deficit Procedure (EDP) for General Government

‡ LTB for long-term bond

§ Preferred measure for labor productivity, see Table 5 and the corresponding text

1.1 Data and Model Consistent Measurement

The data sources and relevant definitions of variables are listed in Table 4. All `.txt` data files listed in Table 3 are created by copying data from the associated `.xlsx` files.

Table 4: Summary of data sources and definitions

Series	Time	Source[a]	Unit	Provided
Output	1980–2015	AMECO (OVGD)	1 billion 2010 constant euro	Yes
Gov. consumption	1980–2015	AMECO (OCTG)	1 billion 2010 constant euro	Yes
Total working hours	1980–2015	AMECO (NLHT)[b]	1 million hours	Yes
Employment	1980–2015	AMECO (NETD)	1000 persons	Yes
Government debt	1980–2015	AMECO EDP[c]	end-of-year % of GDP	Yes
Debt service	1980–2015	AMECO (UYIGE)[d]	end-of-year % of GDP	Yes
Primary surplus	1980–2015	AMECO (UBLGIE)[e]	end-of-year % of GDP	Yes
Bond yields	1980–2015	AMECO (ILN)[f]	%, nominal	Yes
Debt maturity	1990–2010	OECD, Eurostat, ESM[g]	years	Yes
Labor share	1980–2015	AMECO[h]	%	Yes

[a] Strings in parentheses indicate AMECO labels of data series.

[b] PWT 8.1 (Feenstra et al., 2015) values for Greece in 1980–1982.

[c] General government consolidated gross debt; ESA 2010 and former definition, linked series.

[d] AMECO for 1995–2015; European Commission *General Government Data* (GGD, 2002) for 1980–1995.

[e] AMECO linked series for 1995–2015; European Commission *General Government Data* (GGD, 2002) for 1980–1995.

[f] A few missing values for Greece and Portugal replaced by Eurostat long-term government bond yields.

[g] Average across different data sources; sporadic time coverage over countries, see text below; ESM data are obtained from private correspondence.

[h] Compensation of employees (UWCD) plus gross operating surplus (UOGD) minus gross operating surplus adjusted for imputed compensation of self-employed (UQGD), then divided by nominal GDP (UVGD).

To map the data to the model, we construct model consistent data measures for the key variables as below.

Labor input For the aggregate labor input n_{it}, we use two series from AMECO, the aggregate working hours H_{it} and the total employment E_{it} of each country over the period 1980–2015. We calculate the normalized labor input as $n_{it} = H_{it}/(E_{it} \times 5200)$, assuming 100 hours of disposable time per worker per week. However, for most of the data moment computations, we use H_{it} directly, since the per worker annual working hours do not show a significant cyclical pattern and both the level and the trend do not affect the computation of the moments.

Fiscal position and private consumption We hold the premise of fitting the *observed* fiscal behavior across the GIPS countries, so that we use directly the *data measures* of government consumption and primary surplus to calibrate the model. However, the cost of such a strategy is on the model consistent measure of private consumption. Note that in the model, primary surplus equals to $y - g - c$, therefore private consumption equals to y minus the sum of

g and primary surplus. This is the model consistent measure of private consumption we use in our calibration. Nevertheless, due to small magnitudes in primary surplus relative to GDP, the model consistent measure of private consumption tracks closely the dynamics of the alternative data measure of consumption,[2] and the correlation between the two measure is well beyond 0.97.

Government debt, spread, and maturity Since one of the major purposes of this paper is to provide a quantitative assessment of the Euro Area 'stressed' countries, we choose to capture the overall debt burden of those countries by calibrating the general government consolidated gross debt. Indeed, Bocola et al. (2019) argue that matching the overall public debt allows a quantitative sovereign default model to better fit crisis dynamics.

We use the nominal long-term bond yields in AMECO to measure the nominal borrowing costs of the Euro Area 'stressed' countries. For the nominal risk free rate, we use the annualized short-term (3M) interest rates in the Euro money market (obtained from Eurostat with label `irt_st_q`) for 1999–2015, and the annualized short-term (3M) bond return of Germany (obtained from Eurostat with label `irt_h_mr3_q`) for 1980–1998, before the start of Euro. To convert the nominal risk-free rate into real rate, we subtract GDP deflator of Germany from the former series. To arrive at a meaningful measure of the *real* spread, i.e., a spread unaffected by expected inflation hence rightly reflecting the 'stressed' countries' credit risk, we split the sample into two parts. After the introduction of Euro, we can directly use the spread between the 'stressed' countries' long-term nominal bond yields and the nominal risk-free rate, since all rates are denominated in euro and thus subject to the same inflation expectation. The question is much trickier for the period before Euro. Motivated by Du and Schreger (2016), we use spot and forward exchange rates (retrieved from Thomson Reuters' Datastream, accessed through the data subscription of European University Institute in 2017) to convert the German nominal risk free rate into each stressed country's local currency, hence deriving a synthetic local currency risk free rate, and then take the difference between the local nominal long-term bond yield with the synthetic risk free rate. Since the synthetic risk free rate is denominated in the local currency as well, it is subject to the same inflation expectations as the long-term bond yield, and consequently, the difference is equivalent to the real spread.

The information on the maturity structure of the government debt for the GIPS countries is not comprehensive. The detailed sources are provided in `Estimation/data/Debt maturity summary.xlsx`. The overall time coverage is unequal across countries: 1998–2010 and 2014–2015 for Ireland, 1998–2015 for Greece, 1991–2015 for Spain, 1990–2015 for Italy, and 1995–2015 for Portugal.

[2]Indeed, the alternative measure is private absorption defined as the sum of private consumption and investment as measured in the data, since there is no capital in our model.

Replication notice Check the `.xlsx` files in `Estimation/data/` directory for more information on each data file and the constructions on data measurements.

1.2 Productivity Measures

MATLAB script `Acompute.m` contains codes for construction and processing 5 alternative productivity measures, TFP and 4 variants of labor productivities, for GIPS countries.[3] Table 5 summarizes the key contents of the script.

The preferred productivity series is LNP. The configurations for data construction and processing are as following: common labor share, common (log) linear trend, and normalization of both mean and standard deviation, across 4 GIPS countries. The corresponding output file is `ALN-GIPS0012009.txt` for the raw series, and `dlogALN-GIPS0012009.txt` for the log detrended series. The tag `001` corresponds to the detrending options, and `2009` corresponds to the last year before the crisis.

Replication notice To replicate the resulting productivity file, run the `Acompute.m` program under the given parameters and option specifications.

[3] Greece, Italy, Portugal, and Spain.

Table 5: `Acompute.m` for productivity construction and processing

Choice of productivity measures	
LNP	labor productivity with working hours as input
LEP	labor productivity with employment as input
LHP	labor productivity with human capital as input
LCP	labor productivity with composite labor input
TFP	Construct capital series from investment data
Option: Labor share	
`LSme`	0: Common α
	1: Country specific α_i
	2: Country-year specific α_{it}
Option: Detrending specification	
`dtspec`	0: Country specific trend (log linear)
	1: Common trend (log linear)
Option: Detrending method	
`dtspec`	0: Simple average growth rate
	1: Linear trend by OLS fitting
Option: Period for Detrending	
`dtperd`	0: Full sample
	1: Drop the crisis period, starting from 2010
Option: Normalization of detrended log productivity	
`normme`	0: No normalization
	1: Normalize mean by addition
	2: Normalize standard deviation by multiplication
	3: Normalize both mean and standard deviation
Input: Data (`.txt`) directory `data/`	
`AMECO_GDP.txt`	Output
`AMECO_Employment.txt`	Employment
`AMECO_Totalhours.txt`	Total working hours
`AMECO_Humancapital.txt`	Human capital
`AMECO_Investment.txt`	Investment
`AMECO_Laborshare.txt`	Labor income share
Output: Data (`.txt`) directory `productivity/`, figure (`.pdf`) directory `figures/`	
`config.txt`	Configurations
`TFP.txt`	TFP: Level, no detrending
`dlogTFP.txt`, `dlogTFP.pdf`	TFP: Log, detrending
`LXP.txt`	Labor productivity: Level, no detrending
`dlogALX.txt`, `dlogALX.pdf`	Labor productivity: Log, detrending
Mnemonic `X` = `N`, `E`, `H`, `C`	Corresponding to LNP, LEP, LHP, LCP

1.3 Sample Moments

For GIPS countries, MATLAB script `momentsGIPS.m` produces all sample moments relevant for calibration. Table 6 reports the key contents of the script.

Table 6: `momentsGIPS.m` for moments of GIPS

Configuration	
Full sample	1980–2015
Subsample	2000–2015
Call-in program	
`hpfilter.m`	With filtering parameter 6.25
Input: Data directory `data/`, productivity directory `productivity/`	
`AMECO_GDP.txt`	Output
`AMECO_C.txt`	Consumption
`AMECO_G.txt`	Government consumption
`AMECO_Totalhours.txt`	Total working hours
`AMECO_Employment.txt`	Employment
`AMECO_AveHours.txt`	Average working hours
`AMECO_PS.txt`	Primary surplus, constructed
`AMECO_PSG.txt`	Primary surplus, EDP
`AMECO_B.txt`	Debt/GDP
`AMECO_Yield.txt`	LTB yield
`AMECO_Coupon.txt`	LTB coupon rate
`AMECO_GDPDeflator.txt`	GDP Deflator
`AMECO_CPI.txt`	CPI
`Spread_FR.txt`	LTB spread over German bond
`LNP.txt`	Labor productivity
Output: Parental directory `Estimation/`	
`datamoments.txt`	Sample moments

For non GIPS Euro Area countries, MATLAB script `momentsNG.m` produces the sample moments of fiscal policy for comparison. Table 7 reports the key contents of the script.

Table 7: `momentsNG.m` for moments of non GIPS

Configuration	
Full sample	1980–2015
Subsample	2000–2015
Call-in program	
`hpfilter.m`	With filtering parameter 6.25
Input: Data directory `data/`	
`AMECO_GDP_EANG.txt`	Output
`AMECO_PS_EANG.txt`	Primary surplus, constructed
`AMECO_PSG_EANG.txt`	Primary surplus, EDP
Output: Parental directory `Estimation/`	
`datamoments_NG.txt`	Sample moments

Replication notice To replicate the moments reported in the paper, run the `momentsGIPS.m` and `momentsNG.m` programs under the given parameter files and option specifications. Check Table 2 to see the relationship between the tables reported in the paper and the source files generated by the codes.

1.4 Moments Not Reported by MATLAB Scripts

Two moments are directly calibrated using source data without resorting to MATLAB files.

1. `AMECO_RateShort.xlsx` for the average real short-term risk-free rate, using German nominal short-term rate together with GDP deflator.

2. `Debt maturity summary.xlsx` for the average maturity, using data assembled from Eurostat, ESM, and OECD.

2 Productivity Process Estimation and Discretization

2.1 Estimation

We model the productivity process as a Markov regime switching (MRS) process, and use a panel MRS model to estimate the process from the labor productivity series of GIPS. For technical details, see document `notes/PanelMRS.pdf`. The estimation programs consist of four MATLAB files, as described below.

1. `PanelMRS.m` is the main script, containing five parts:

   (a) Initialization under several specifications;

(b) Estimation, calling MATLAB function `PanelMRSem.m`;

(c) Results reporting, with a diary file recording formatted results displayed on the command window;

(d) Inference, calling MATLAB function `PanelMRSinf.m`;

(e) Plotting smoothed regime probability using results from estimation or a single run of `PanelMRSem.m`.

`PanelMRS.m` serves two purposes: single run estimation, or reporting results on estimation and inference and plotting for an existing estimation.

The **input files** are:

(a) `data/AMECO_countrycode.txt` for country codes.

(b) `productivity/dlogALN-GIPS0012009.txt` for the productivity series used.

(c) `productivity/config-GIPS0012009.txt` for the productivity measure configuration.

(d) `estimation results/initial_guess.txt` for an initialization given by the user.

(e) `estimation results/para-dlogALN-GIPS0012009.txt` for an initialization using an existing estimation result, mainly for the purpose of conducting inference after the estimation procedure executed by `PanelMRS_GS.m`.

The **output files** are:

(a) `estimation results/Results dlogALN-GIPS0012009.txt` for estimation results.

(b) `figures/psY dlogALN-GIPS0012009.pdf` for the smoothed regime probabilities for the sample countries.

For more options or specifications, see remarks in the MATLAB script.

Notes on default use: the default behavior of `PanelMRS.m` is to do inference and plotting, by setting the initialization according to an existing estimation.

2. `PanelMRSem.m` is a function implementing the expectation maximization procedure used in the estimation algorithm.

3. `PanelMRSinf.m` is a function generating inference results for an existing estimation. The default option is to use the score vector, and the alternative is to compute numerical Hessian matrix.

4. `PanelMRS_GS.m` is an auxiliary script to do a global search with multiple random initialization, in order to overcome the problem of local maximum for a fixed initial point used in the EM algorithm. In the default setting, we feed the global search outcome into `PanelMRS.m` for result reporting, inference, and plotting. The default number of random initializations is 50,000. Results are essentially the same with 10,000 random initializations.

   The input files are:

(a) `data/AMECO_countrycode.txt` for country codes.

(b) `productivity/dlogALN-GIPS0012009.txt` for the productivity series used.

(c) `productivity/config-GIPS0012009.txt` for the productivity measure configuration.

The output files are:

(a) `Estimation results/Global search.txt` for the records of global searches.

(b) `Estimation results/Results dlogALN-GIPS0012009-50000.txt` for the global search results with 50,000 random initializations.

(c) `Estimation results/Para-dlogALN-GIPS0012009-50000.txt` for the final estimation result of global search to be used by other programs.

Replication notice First, run `PanelMRS_GS.m` to obtain estimates of the MRS process; second, run `PanelMRS.m` to obtain formatted estimation results, inference, and regime probability plot. Keep the given parameters and option specifications unchanged. Check Table 2 to see the relationship between the results reported in the paper and the source files generated by the codes.

2.2 Discretization

We have developed a systematic approach for discretizing the MRS process. For technical details, see document `notes/MRS Discretization.pdf`. The main MATLAB script for discretization is `DiscretizeMRS.m`, which invokes MATLAB function `RowenhorstTM.m` to construct the transition matrices. The script also generates a comparison of the sample moments for the raw productivity process, the theoretical moments for the MRS process, and the theoretical moments for the discretized process, with results displayed on the command window.

The **input files** are:

1. `productivity/dlogALN-GIPS0012009.txt` for comparison purpose;
2. `estimation results/Para-dlogALN-GIPS0012009.txt` for the MRS estimate.

The **output file** is:

1. `discretization/shockALN-GIPS0012009n.txt` for the discretized productivity state space and transition matrix, where `n` indicates the final version used in the solution and simulation programs. One should copy this file into the `Solution/` directory, to be used for both the FORTRAN codes of IMD solution, and MATLAB codes of Fund solution and simulation.

Notes for normalization The final discretized state space is in level, not in logarithm as the input, and follows an *ad hoc* normalization rule of

$$z_i = 3[\exp(x_i - x_{\min} + 2) - \exp(2)]/50 + \exp(2)/50,$$

where x_i denotes the log productivity discretized from the MRS process and $x_{\min} = \min\{x_i\}$.

The main **option** for discretization procedure is whether to replicate the sample coefficient of variation of the (log) productivity series. The default option is not to replicate.

Replication notice To replicate the shock file used subsequently, run the `DiscretizeMRS.m` program under the given parameter files and option specifications.

3 IMD Solution: FORTRAN

The directory is `Solution/`, the main FORTRAN script is `valueMH.f90`, and the FORTRAN project file is `FortranMH.sln`. One should open `FortranMH.sln` directly. The FORTRAN program we use is Intel Fortran Compiler Classic, which is contained in Intel oneAPI HPC toolbox. The DEI we use is Visual Studio 2022. Most of the time, we run the IMD solution code on a work station with Intel I9 CPU and 128 GB memory. The average time for each iteration is around 1 minute. If we run code from 0 initial (i.e., taking limit of a finite horizon model), then in general it takes 300 iterations for the value function to converge under 'reasonable' parameter values. We have checked results from 500 to 1,000 iterations, and the differences are quantitatively indistinguishable.

Input file There is only one input file.

1. `shockALN-GIPS0012009n.txt` contains the discretized labor productivity process.

Output files There are 8 output files in together.

1. `cvg_path.txt` contains the summary of each iteration in the value iteration procedure.
2. `grid_info.txt` contains the key parameters of the grid specifications for the bond holding, productivity shock, and government consumption shock.
3. `parameter_MH.txt` contains all parameters other than grid specifications.
4. `resultsd1_MH.txt` contains value and policy functions at exactly default thresholds across the shock states.
5. `resultsd2_MH.txt` contains value and policy functions over the state space grid.
6. `shockG_MH.txt` contains the government consumption shock constructed in the FORTRAN script, with the iid component.
7. `shockGcGd_MH.txt` contains the cyclical component g^c of the government consumption shock, and the grid specification for the iid component g^d, separately.
8. `solution_method.txt` contains all solution and option configuration of the FORTRAN solution procedure.

Replication notice To replicate the IMD solution, simply run the `valueMH.f90` program within the FORTRAN project `FortranMH.sln` under the given parameter values and option specification. The program should stop within 1 iteration. Note that under the given option specification, no results are saved to replace the existing ones.

IM solution The `valueMH.f90` also provides the standard no-default incomplete market economy (IM) solution under suitable options specified at the beginning of the code, and the output files are `results1_MH.txt` and `results2_MH.txt`. Proper debt limit should be specified in the grid of the debt. IM solutions are required for welfare decomposition, cf. Section 7.

There are two more output files, `shockG_IM_MH.txt` and `shockGcGd_IM_MH.txt`, which are used for certain subsequent simulation exercises where we omit the iid component for the g shock.

4 Fund Solution: MATLAB

The directory is `Solution/`, the main MATLAB script `optimalFSF_MH.m` computes the solution to the optimal Fund contract with moral hazard and the decentralization of the optimal contract. The related input/output files and called-in functions are as follows. Check the remarks in the script for various options controlling computations. Note that to compute the solution for the Fund economy (two-sided lack of commitment), it is always necessary to first compute the first best solution, so that the option `FB` and `LC2` should both be set to 1 simultaneously. The current solution `plc_MH.mat` contains solutions for the 4 economies: the first best, the Fund, the one-sided lack of commitment, and the two-sided lack of commitment with observable effort.

Input files There are 6 input files.

1. `grid_info.txt` for grid information on shocks.
2. `parameter_MH.txt` for the parameters related to a particular solution.
3. `shockALN-GIPS0012009n.txt` for the labor productivity shock process.
4. `shockGcGd_MH.txt` for the g shock process, and in particular the two extreme transition matrices.
5. `resultsd1_MH.txt` for autarky values, where the outside option of the borrower is to enter IMD default case upon leaving the Fund. This is the default option used in the paper.
6. `resultsd2_MH.txt` for alternative autarky values, where the outside option of the borrower is to enter IMD repayment case with 0 debt, i.e., the values obtained by the borrower upon re-entering the IMD credit market, once leaving the Fund.

Output files There is 1 output file.

1. `plc_MH.mat` for the policy functions of the Fund solution, in the format of MATLAB working space file.

Called-in functions There are 6 MATLAB functions used by `optimalFSF_MH.m`.

1. `fncom.m` solves for optimal labor.
2. `fcefffb.m` solves for the optimal effort.
3. `particip_basymeff.m` evaluates the borrower's participation constraint.
4. `particip_basymeffoe.m` evaluates the borrower's participation constraint under observable effort setup.
5. `particip_lasym.m` evaluates the lender's participation constraint.
6. `particip_lasymeffoe.m` evaluates the lender's participation constraint under observable effort setup.

Replication notice To replicate the Fund solution, simply run the `optimalFSF_MH.m` program under the given parameter files and option specification. The program should stop within 1 iteration. Note that under the given option specification, no results are saved to replace the existing ones.

5 Policy Function Plotting: MATLAB

The directory is `Solution/`, and the MATLAB script `policiesplot_MH.m` plots various policy functions for the Fund solution.

Input files There are 8 input files.

1. `grid_info.txt` for grid information on shocks.
2. `parameter_MH.txt` for the parameters related to a particular solution.
3. `shockALN-GIPS0012009n.txt` for the labor productivity shock process.
4. `shockG_MH.txt` for the compound g shock process.
5. `shockGcGd_MH.txt` for the g shock process, with two components separately.
6. `resultsd1_MH.txt` for autarky values of IMD.
7. `resultsd2_MH.txt` for policy functions of IMD.
8. `plc_MH.mat` for the Fund solution.

Output files All output figures are saved in the relevant `figures/` directory.

Replication notice To replicate the figures reported in the paper, run the `policiesplot_MH.m` program under the given parameter files and option specifications. Check Table 2 to see the relationship between the figures reported in the paper and the source files generated by the code.

6 Simulation: MATLAB

The simulation program consists of 4 MATLAB scripts and 2 auxiliary MATLAB functions, as described below.

1. `simulations.m`: the main script, specifying simulation setups for different tasks, invoking functional script for IMD, Fund, and IM solutions.
2. `simuIMD.m`: the script simulating results for IMD solutions.
3. `simuIM.m`: the script simulating results for IM solutions; not actively used.
4. `simuFSF.m`: the script simulating results for Fund solutions.
5. `hpfilter.m`: function of HP filter, used in the calculation of second moments for calibration.
6. `defaultplot.m`: function for drawing default areas in the long-run simulations.

The simulation program is highly integrated, and covers many options and configurations. In particular, the program covers the solutions both with and without moral hazards, with different specifications for two types of solutions. There are 8 types of simulations in total.

1. `short`: short run simulations with many cross-section units for calibration purpose, with many moments calculated with the simulated data.
2. `counterfact`: counterfactual simulations with many cross-section units with fixed initial states
3. `long`: long run simulation with single cross-section unit, starting from the average debt/asset level.
4. `longhb`: same as `long`, but starting from a given debt/asset to GDP ratio.
5. `acrisis`: similar to `long`, but with shocks fixed at the worst case.
6. `transition`: simulations with many cross-section units, with debt/asset to GDP ratio set to a given level at a common time period across units, while keeping underlying shock processes at the ergodic distribution.
7. `impulseneg`: impulse responses from bad productivity and g shock.
8. `impulseneg_g`: impulse responses from bad g shock.
9. `impulseneg_t`: impulse responses from bad productivity shock.

Input files The same as policy plotting script `policiesplot_MH.m`.

Output files All figures are saved in the relevant `figures/` directory, with two more `.txt` files recording simulation statistics:

1. `IMD statistics.txt` and `FSF statistics.txt` for the solutions without moral hazard.
2. `IMD_MH statistics.txt` and `FSF_MH statistics.txt` for the solutions with moral hazard.

Lastly, there are quite a few data files generated in the simulation, and see the codes for details.

Notes on the execution order To run the simulation, an IMD solution always goes first, followed by the corresponding Fund solution. For each solution, always run `short` simulation first, and it is a good idea to follow the order listed above for the 8 types of simulations. Note each type of simulation should be run separately, to avoid any interference among different types of simulation.

Replication notice To replicate the tables reported in the paper, run the `simulations.m` program under the given parameter files and option specifications in the following order:

1. `short = 1`: generate model moments for both the IMD and Fund solution, with `IMD = 1` and `FSF = 1` in turn respectively.
2. `long = 1`: simulate the paths for the IMD and Fund solution respectively and plot the 2 figures, with `FSF = 1` only, as the IMD simulation is saved.
3. `counterfact = 1`: counterfactual simulations for the crisis periods and plot the 2 figures, with `FSF = 1` only, as the IMD simulation is saved.
4. `counterfact = 1`: default wave simulation and plot the figure, with `IMD = 1` only.

Check Table 2 to see the relationship between the figures reported in the paper and the source files generated by the code.

7 Welfare Evaluation: MATLAB

There is only one MATLAB script `welfare.m`, serving two purposes:

1. Compute welfare gains of Fund over IMD;
2. Decompose the welfare gains into 4 components.

Each functionality is controlled by an option; see the codes for details. The program is integrated to cover both moral hazard and non moral hazard setups. However, since the focus is on the moral hazard case, we shall omit the non moral hazard case below.

Input files `welfare.m` also invokes all the input files as in the policy plotting and simulation part. However, for the welfare decomposition task, the script also invokes IM solutions in subdirectory `IM#/`. See `A_FSF.txt` for details on the specifications for each IM solution, i.e., the borrowing limit.

Output files All figures are saved into the relevant `figures/` directory. Moreover, there are two types of `.txt` files recording the welfare evaluation results.

1. `welfare_conditional_MH.txt` contains tables for welfare gains.
2. `welfare_decomposition_MH_k` contains tables for welfare decomposition results associated with kth IM solution, and is placed in `IMk/` directory.

Replication notice First, run the welfare comparison part of `welfare.m` with `WC = 1` to obtain welfare gains, without turning on the welfare decomposition part `WD = 0`. Second, turn down the welfare comparison part `WC = 0`, run the welfare decomposition part of `welfare.m` with `WD = 1`, and set the IM solution number to be `sonoim = 1` and `sonoim = 4` in turn, to obtain the decomposition under the two IM solutions. Check Table 2 to see the relationship between the figures reported in the paper and the source files generated by the code.

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