

Matlab Toolbox Heterogeneous Agents Dynamic Programming

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Preface

This is a work-in-progress Matlab package consisting of functions that facilitate Dynamic Programming and Related Tasks. Materials gathered from various [projects](#) in which Matlab code is used. Some of the solutions/algorithms are research outputs developed for specific research [papers](#), other algorithms and methods are commonly-used. Files are the [MEconTools](#) repository. Matlab files are linked below by section with livescript files. Tested with [Matlab 2019a](#) (The MathWorks Inc, 2019).

Download and install the Matlab toolbox: [MEconTools.mltbx](#)

This bookdown file is a collection of mlx based vignettes for functions that are available from [MEconTools](#). Each Vignette file contains various examples for invoking each function. The goal of this repository is to make it easier to find/re-use codes produced for various projects.

From other repositories: For dynamic borrowing and savings problems, see [Dynamic Asset Repository](#); For code examples, see also [R Example Code](#), [Matlab Example Code](#), and [Stata Example Code](#); For intro stat with R, see [Intro Statistics for Undergraduates](#), and intro Math with Matlab, see [Intro Mathematics for Economists](#). See [here](#) for all of Fan's public repositories.

The site is built using [Bookdown](#) (Xie, 2020).

Please contact [FanWangEcon](#) for issues or problems.

Chapter 1

Savings Dynamic Programming

1.1 FF_VFI_AZ_LOOP Savings Loop Grid Examples

Go back to [fan's MEconTools Toolbox \(bookdown\)](#), [Matlab Code Examples Repository \(bookdown\)](#), or [Math for Econ with Matlab Repository \(bookdown\)](#).

This is the example vignette for function: [`ff_vfi_az_loop`](#) from the [MEconTools Package](#). This function solves the dynamic programming problem for a (a,z) model. Households can save a, and face AR(1) shock z. The problem is solved over the infinite horizon.

This is the **looped** code, it is slow for larger state-space problems. The code uses **common grid**, with the same state space and choice space grids.

Links to Other Code:

Core Savings/Borrowing Dynamic Programming Solution Functions that are functions in the [MEconTools Package](#) :

- Common Choice and States Grid : [`ff_vfi_az_loop`](#)
- Common Choice and States Grid : [`ff_vfi_az_vec`](#)
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand, rely on FOC, :[`ff_vfi_az_bisec_loop`](#)
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand, rely on FOC : [`ff_vfi_az_bisec_vec`](#)
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand, VALUE comparison, :[`ff_vfi_az_mzoom_loop`](#)
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand, VALUE comparison, :[`ff_vfi_az_mzoom_vec`](#)

The sample codes are written for the standard dynamic savings problem. The code can be adapted for multiple assets, savings and borrowing, discrete and continuous choice, etc. A large proportion of dynamic economic models are based on the underlying structure of solving a model with endogenous states and exogenous shocks, and that is what the (a,z) model does. In general, one can write looped code first to make sure the economics is correct, then vectorized code can be adopted to increase speed.

1.1.1 Test FF_VFI_AZ_LOOP Defaults

Call the function with defaults. By default, shows the asset policy function summary. Model parameters can be changed by the mp_params.

```
%mp_params  
mp_params = containers.Map('KeyType','char', 'ValueType','any');  
mp_params('fl_crra') = 1.5;  
mp_params('fl_beta') = 0.94;  
% call function
```

```

ff_vfi_az_loop(mp_params);

Elapsed time is 2.378952 seconds.
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

      i   idx  ndim  numel  rowN  colN    sum   mean    std  coefvari  min
      -   ---  ----  -----  ----  ----  -----  -----  -----  -----  -----
ap     1     1     2     700    100      7  9855.1  14.079  14.408  1.0234     0

xxx TABLE:ap xxxxxxxxxxxxxxxxxxxxxxxx
      c1     c2     c3     c4     c5     c6     c7
      ----  ----  ----  -----  -----  -----  -----
r1      0      0      0  0.045213  0.25576  0.61095  1.0362
r2      0      0      0  0.045213  0.25576  0.61095  1.0362
r3      0      0      0  0.045213  0.25576  0.61095  1.0362
r4      0      0      0  0.06647   0.25576  0.61095  1.0362
r5      0      0      0  0.06647   0.25576  0.61095  1.164
r96    43.924  43.924  43.924  43.924   43.924  45.102  45.102
r97    45.102  45.102  45.102  45.102   45.102  46.298  46.298
r98    46.298  46.298  46.298  46.298   46.298  47.513  47.513
r99    47.513  47.513  47.513  47.513   47.513  48.747  48.747
r100   48.747  48.747  48.747  48.747   48.747      50      50

```

1.1.2 Test FF_VFI_AZ_BISEC_VEC Speed Tests

Call the function with different a and z grid size, print out speed:

```

mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_timer') = true;
mp_support('ls_ffcmd') = {};
% A grid 50, shock grid 5:
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 50;
mp_params('it_z_n') = 5;
ff_vfi_az_loop(mp_params, mp_support);

```

Elapsed time is 0.715890 seconds.

```

% A grid 750, shock grid 15:
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 750;
mp_params('it_z_n') = 15;
ff_vfi_az_loop(mp_params, mp_support);

```

Elapsed time is 300.576571 seconds.

```

% A grid 600, shock grid 45:
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 600;
mp_params('it_z_n') = 45;
ff_vfi_az_loop(mp_params, mp_support);

```

Elapsed time is 910.111661 seconds.

1.1.3 Test FF_VFI_AZ_LOOP Control Outputs

Run the function first without any outputs, but only the timer.

```
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 50;
mp_params('it_z_n') = 5;
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_timer') = true;
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {};
ff_vfi_az_loop(mp_params, mp_support);
```

Elapsed time is 0.400105 seconds.

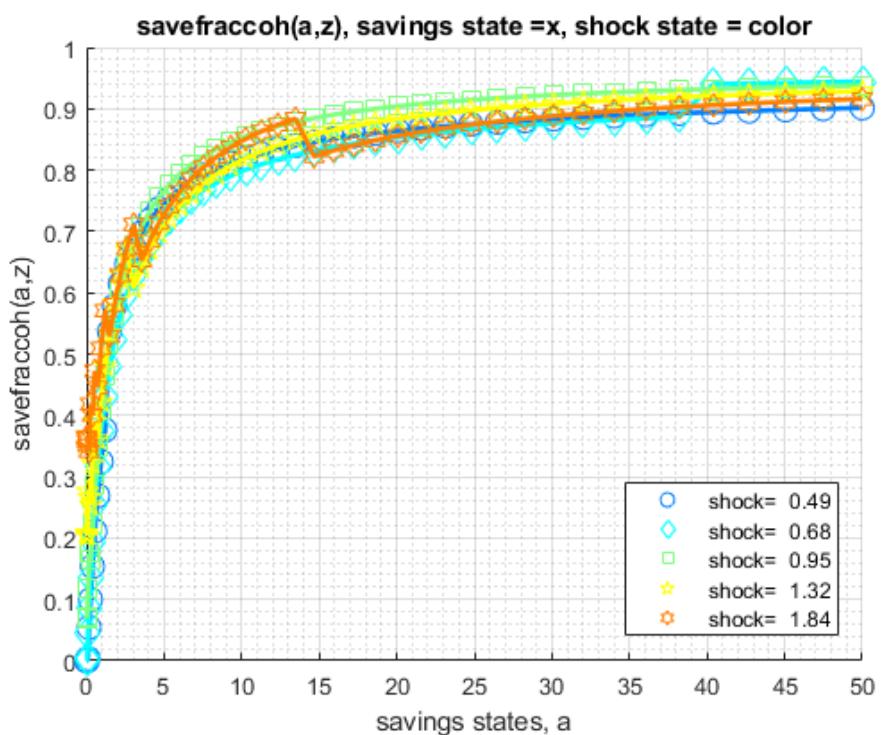
Run the function and show policy function for savings choice. For ls_ffcmd, ls_ffsna, ls_ffgrh, can include these: 'v', 'ap', 'c', 'y', 'coh', 'savefraccoh'. These are value, aprime savings choice, consumption, income, cash on hand, and savings fraction as cash-on-hand.

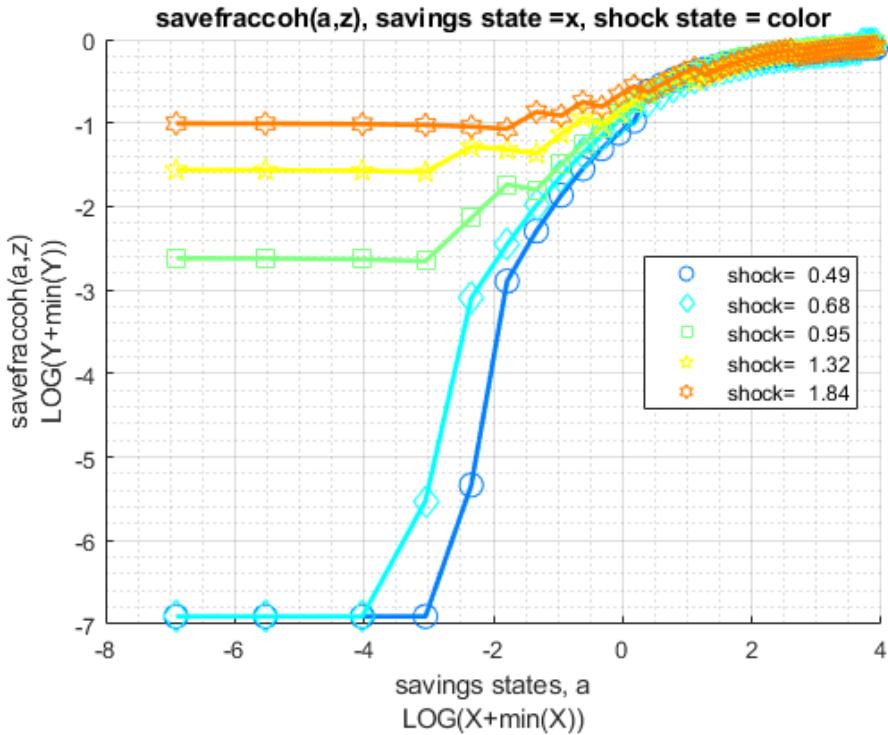
```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
% ls_ffcmd: summary print which outcomes
mp_support('ls_ffcmd') = {};
% ls_ffsna: detail print which outcomes
mp_support('ls_ffsna') = {'savefraccoh'};
% ls_ffgrh: graphical print which outcomes
mp_support('ls_ffgrh') = {'savefraccoh'};
ff_vfi_az_loop(mp_params, mp_support);
```

Elapsed time is 0.410866 seconds.

xxx ff_vfi_az_vec, outcome=savefraccoh		xxxxxxxxxxxxxxxxxxxxxxxxxxxx	mean_z_0_4858	mean_z_0_67798	mean_z_0_9462	mean_z_1_3205	mean_z_
group	a						
1	0		0	0	0.071865	0.20862	0.3
2	0.002975		0	0	0.071698	0.20827	0.3
3	0.016829		0	0	0.070928	0.20666	0.3
4	0.046375		0	0.0029827	0.069341	0.20331	0.3
5	0.095198	0.0038183		0.044243	0.11681	0.27649	0.3
6	0.1663	0.054362		0.084837	0.17517	0.26637	0.3
7	0.26234	0.099899		0.13609	0.16422	0.25383	0.4
8	0.38568	0.15381		0.19428	0.22348	0.32132	0.4
9	0.53852	0.21153		0.25554	0.28573	0.39055	0.4
10	0.72291	0.26934		0.31659	0.34814	0.36175	0.4
11	0.94076	0.3247		0.37504	0.40848	0.42229	0.5
12	1.1939	0.37617		0.42941	0.46521	0.4802	0.5
13	1.484	0.53695		0.47898	0.51743	0.5344	0.
14	1.8128	0.57847		0.52356	0.56473	0.58429	0.5
15	2.1817	0.61468		0.56329	0.6071	0.62958	0.6
16	2.5924	0.6462		0.5985	0.64475	0.67028	0.6
17	3.0463	0.67365		0.62963	0.67804	0.60721	0.7
18	3.5449	0.69762		0.65713	0.70737	0.6404	0.6
19	4.0894	0.71859		0.68142	0.73318	0.67021	0.6
20	4.6813	0.73701		0.70293	0.75587	0.6969	0.7
21	5.3218	0.75325		0.722	0.77584	0.72078	0.7
22	6.0121	0.76763		0.73895	0.79344	0.74211	0.7
23	6.7536	0.7804		0.75407	0.80897	0.76119	0.7
24	7.5474	0.7918		0.76759	0.8227	0.77824	0.8

25	8.3948	0.80201	0.77972	0.83486	0.79351	0.8
26	9.2967	0.81119	0.79063	0.84567	0.80719	0.8
27	10.254	0.81947	0.80049	0.85553	0.81948	0.8
28	11.269	0.82697	0.80941	0.86389	0.83053	0.8
29	12.342	0.83379	0.81752	0.87159	0.84048	0.8
30	13.473	0.84001	0.8249	0.87849	0.84946	0.8
31	14.665	0.84569	0.83165	0.8847	0.85759	0.8
32	15.918	0.8509	0.83782	0.8903	0.86495	0.8
33	17.233	0.8557	0.8435	0.89536	0.87163	0.8
34	18.611	0.86012	0.84872	0.89995	0.8777	0.8
35	20.053	0.86421	0.85354	0.90411	0.88324	0.8
36	21.56	0.86799	0.858	0.9079	0.8883	0.8
37	23.133	0.87151	0.86214	0.91136	0.89292	0.8
38	24.773	0.87479	0.86598	0.91452	0.89716	0.8
39	26.481	0.87784	0.86955	0.91741	0.90105	0.8
40	28.258	0.8807	0.87289	0.92007	0.90463	0.8
41	30.104	0.88337	0.87601	0.92251	0.90793	0.8
42	32.021	0.88588	0.87893	0.92475	0.91097	0.
43	34.01	0.88824	0.88166	0.92683	0.91378	0.8
44	36.07	0.89046	0.88423	0.92874	0.91638	0.8
45	38.204	0.89256	0.88665	0.93052	0.91879	0.9
46	40.412	0.89453	0.9403	0.93216	0.92102	0.9
47	42.695	0.8964	0.94141	0.93368	0.9231	0.9
48	45.053	0.89817	0.94245	0.9351	0.92504	0.9
49	47.488	0.89985	0.94341	0.93642	0.92684	0.
50	50	0.90144	0.9443	0.93765	0.92853	0.9





Run the function and show summaries for savings and fraction of coh saved:

```
mp_params('it_a_n') = 100;
mp_params('it_z_n') = 9;
mp_support('ls_ffcmd') = {'ap', 'savefraccoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {};
mp_support('bl_vfi_store_all') = true; % store c(a,z), y(a,z)
ff_vfi_az_loop(mp_params, mp_support);
```

Elapsed time is 3.281815 seconds.

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coef
-	---	----	-----	-----	----	----	-----	-----	-----	-----
ap	1	1	2	900	100	9	12904	14.338	14.524	1.
savefraccoh	2	2	2	900	100	9	619.51	0.68834	0.26953	0.39

xxx TABLE:ap xxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6	c7	c8
	-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0.092813	0.25576	0.61095	1.0362
r2	0	0	0	0	0.092813	0.25576	0.61095	1.0362
r3	0	0	0	0	0.092813	0.25576	0.61095	1.0362
r4	0	0	0	0.00051272	0.092813	0.25576	0.61095	1.0362
r5	0	0	0	0.0029004	0.092813	0.25576	0.61095	1.0362
r96	43.924	43.924	43.924	43.924	43.924	45.102	45.102	45.102
r97	45.102	45.102	45.102	45.102	45.102	46.298	46.298	46.298
r98	46.298	46.298	46.298	46.298	46.298	47.513	47.513	47.513
r99	47.513	47.513	47.513	47.513	47.513	48.747	48.747	48.747

r100	48.747	48.747	48.747	48.747	48.747	50	50	50
xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxxxxxxxx								
	c1	c2	c3	c4	c5	c6	c7	c8
-----	-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0.070073	0.15255	0.28789	0.38573
r2	0	0	0	0	0.070045	0.1525	0.28781	0.38565
r3	0	0	0	0	0.069914	0.15228	0.28748	0.3853
r4	0	0	0	0.00048613	0.069636	0.1518	0.28676	0.38454
r5	0	0	0	0.0027273	0.069182	0.15101	0.28559	0.38329
r96	0.92625	0.92358	0.92022	0.916	0.91072	0.92836	0.91992	0.90945
r97	0.92676	0.92416	0.92088	0.91677	0.91162	0.92918	0.92095	0.91073
r98	0.92727	0.92473	0.92153	0.91752	0.91249	0.92998	0.92194	0.91196
r99	0.92776	0.92528	0.92216	0.91824	0.91333	0.93076	0.92291	0.91315
r100	0.92823	0.92581	0.92277	0.91895	0.91416	0.93151	0.92384	0.91431

1.1.4 Test FF_VFI_AZ_LOOP Change Interest Rate and Discount

Show only save fraction of cash on hand:

```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {'savefraccoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {};
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 100;
mp_params('it_z_n') = 7;
mp_params('fl_a_max') = 50;
mp_params('st_grid_type') = 'grid_powerspace';
```

Solve the model with several different interest rates and discount factor:

```
% Lower Savings Incentives
mp_params('fl_beta') = 0.80;
mp_params('fl_r') = 0.01;
ff_vfi_az_loop(mp_params, mp_support);
```

Elapsed time is 0.825240 seconds.

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefva
	-	---	----	----	----	----	----	----	----	----
savefraccoh	1	1	2	700	100	7	357.49	0.5107	0.2755	0.5394
xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxxxxxxxx										
	c1	c2	c3	c4	c5	c6	c7			
-----	-----	-----	-----	-----	-----	-----	-----			
r1	0	0	0	0	0	0	0.0002246	0.041573		
r2	0	0	0	0	0	0	0.00022455	0.041566		
r3	0	0	0	0	0	0	0.0012689	0.041533		
r4	0	0	0	0	0	0	0.001266	0.041462		
r5	0	0	0	0	0	0	0.0034759	0.041345		
r96	0.78455	0.78145	0.79995	0.79456	0.7876	0.77865	0.76719			

```

r97    0.78669   0.78366   0.77972   0.79679   0.78998   0.78122   0.77001
r98    0.78878   0.78582   0.78197   0.79897   0.79231   0.78374   0.77276
r99    0.79084   0.78794   0.78417   0.77927   0.79459   0.7862    0.77545
r100   0.79285   0.79001   0.78633   0.78154   0.79682   0.7886    0.77808

% Higher Savings Incentives
mp_params('fl_beta') = 0.95;
mp_params('fl_r') = 0.04;
ff_vfi_az_loop(mp_params, mp_support);

Elapsed time is 2.386791 seconds.
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

      i     idx    ndim   numel   rowN   colN     sum   mean    std   coef
      -     ---    ----   -----   ----   ----   -----   -----   -----   -----
savefraccoh  1       1      2      700    100      7    479.94  0.68563  0.27152  0.39

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx
      c1     c2     c3     c4     c5     c6     c7
      ----  -----  -----  -----  -----  -----  -----
r1      0       0      0    0.07007  0.17967  0.30874  0.43404
r2      0       0      0    0.070042 0.17961  0.30866  0.43396
r3      0       0      0    0.069911 0.17935  0.30833  0.4336
r4      0       0      0    0.069633 0.17881  0.30762  0.43284
r5      0       0    0.00049972 0.069179 0.17792  0.30645  0.43158
r96    0.92489  0.92134  0.91672  0.91072  0.92717  0.91691  0.92776
r97    0.92544  0.92198  0.91747  0.91162  0.92802  0.91801  0.92895
r98    0.92598  0.9226   0.9182   0.91249  0.92885  0.91908  0.9301
r99    0.9265   0.9232   0.91891  0.91333  0.92965  0.92011  0.93121
r100   0.927    0.92379  0.9196   0.91416  0.93042  0.9211   0.90914

```

1.1.5 Test FF_VFI_AZ_LOOP Changing Risk Aversion

Here, again, show fraction of coh saved in summary tabular form, but also show it graphically.

```

mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {'savefraccoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {'savefraccoh'};
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 100;
mp_params('it_z_n') = 7;
mp_params('fl_a_max') = 50;
mp_params('st_grid_type') = 'grid_powerspace';

```

Solve the model with different risk aversion levels, higher preferences for risk:

```

% Lower Risk Aversion
mp_params('fl_crpa') = 0.5;
ff_vfi_az_loop(mp_params, mp_support);

```

Elapsed time is 1.327261 seconds.

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

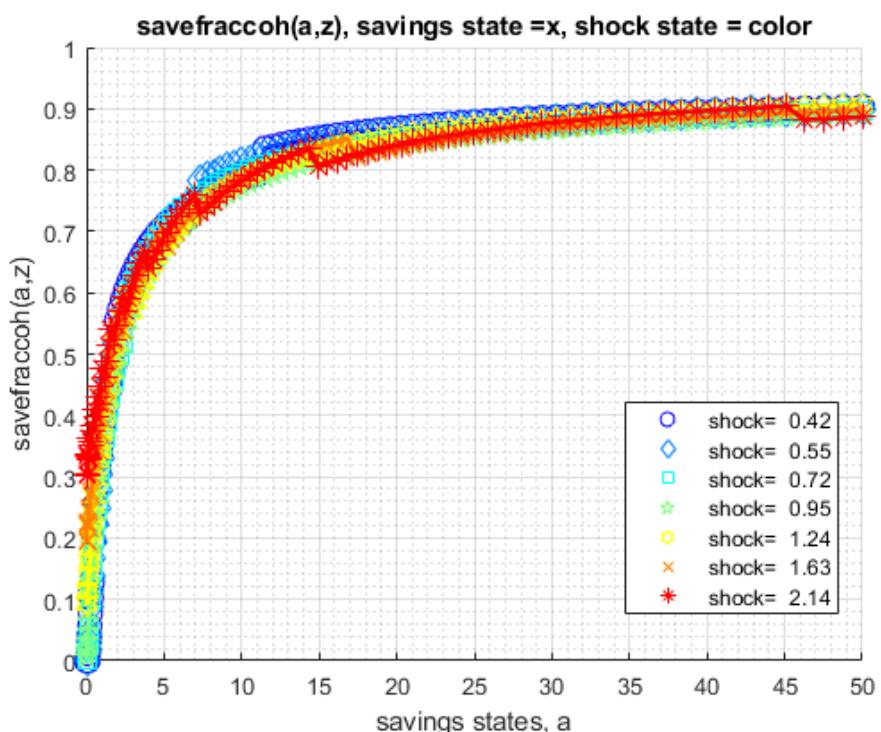
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)

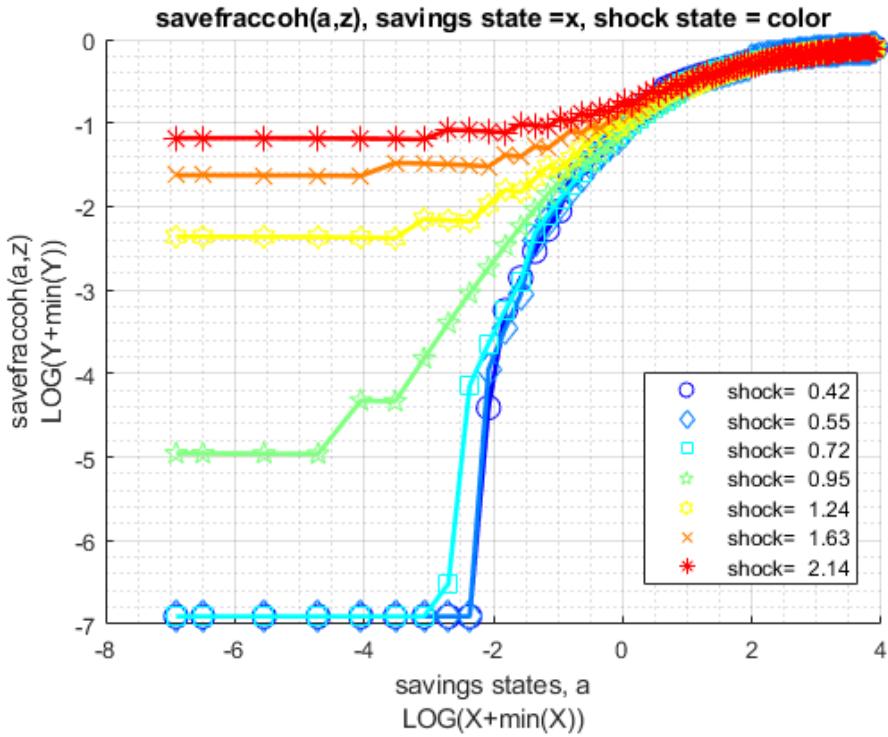
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefv
	-	---	----	-----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	700	100	7	450.35	0.64336	0.2803	0.435

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6	c7
	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0.0060341	0.093241	0.19572	0.30604
r2	0	0	0	0.0060316	0.093213	0.19567	0.30599
r3	0	0	0	0.0060204	0.09308	0.19546	0.30574
r4	0	0	0	0.0059964	0.092798	0.19501	0.3052
r5	0	0	0	0.012229	0.092335	0.19427	0.30431
r96	0.90049	0.89703	0.89253	0.88669	0.90296	0.89297	0.90379
r97	0.90128	0.89791	0.89351	0.88781	0.90404	0.89429	0.88181
r98	0.90205	0.89876	0.89447	0.88891	0.9051	0.89557	0.88337
r99	0.9028	0.89959	0.89541	0.88998	0.90612	0.89681	0.88489
r100	0.90354	0.9004	0.89632	0.89101	0.90711	0.89802	0.88636





When risk aversion increases, at every state-space point, the household wants to save more.

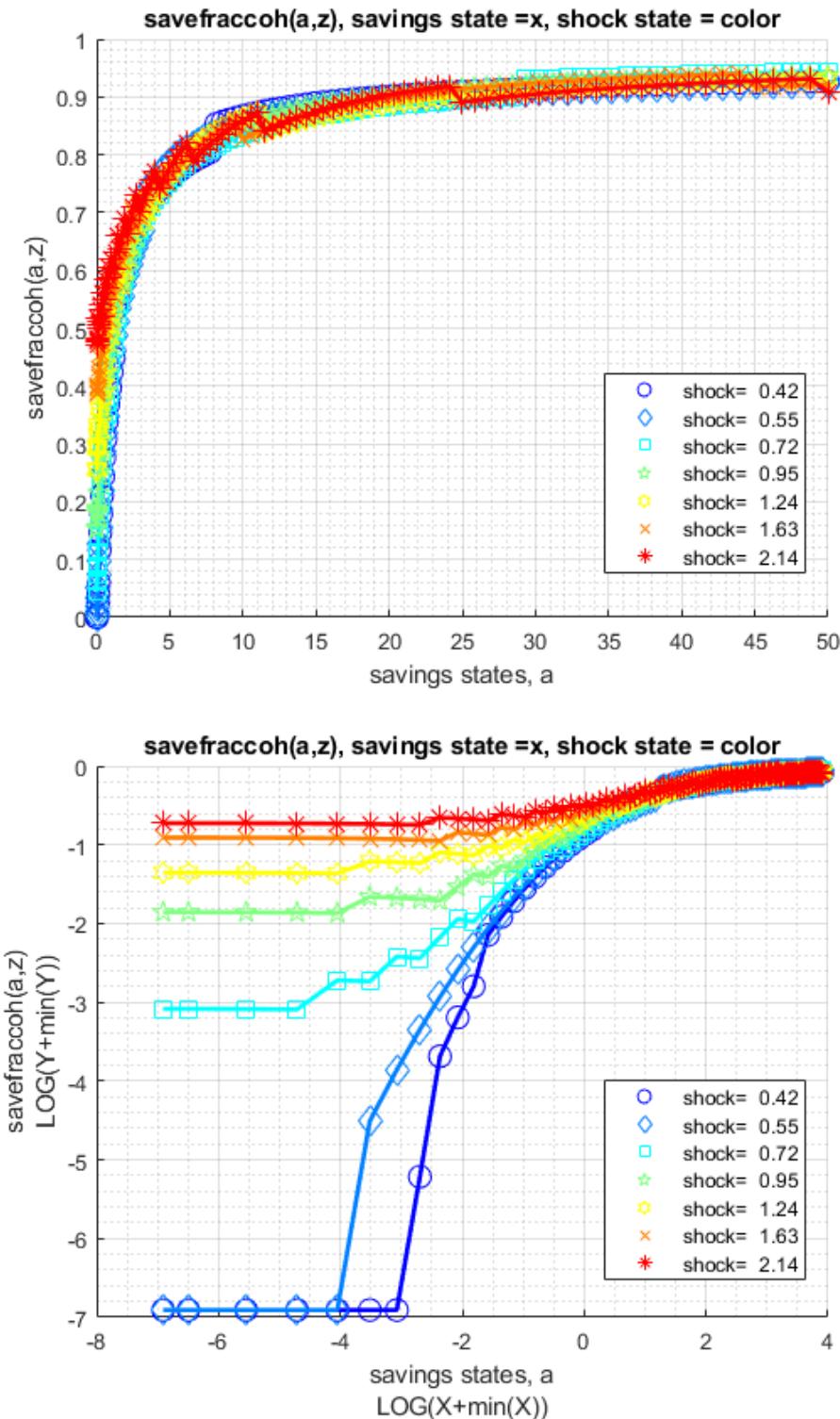
```
% Higher Risk Aversion
mp_params('fl_crra') = 5;
ff_vfi_az_loop(mp_params, mp_support);

Elapsed time is 2.680109 seconds.
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coef
	-	---	----	-----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	700	100	7	500.59	0.71513	0.25488	0.35

```
xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx
   c1      c2      c3      c4      c5      c6      c7
   -----  -----  -----  -----  -----  -----  -----
r1       0       0  0.044811  0.15534  0.25694  0.40177  0.48276
r2       0       0  0.044787  0.15528  0.25686  0.40168  0.48268
r3       0       0  0.044678  0.15499  0.2565   0.40124  0.48228
r4       0       0  0.044445  0.15437  0.25572  0.40032  0.48143
r5       0       0  0.064784  0.15337  0.25445  0.39879  0.48003
r96  0.92489  0.92134  0.94129  0.93513  0.92717  0.91691  0.92776
r97  0.92544  0.92198  0.9418   0.9358   0.92802  0.91801  0.92895
r98  0.92598  0.9226   0.9423   0.93644  0.92885  0.91908  0.9301
r99  0.9265   0.9232   0.94278  0.93706  0.92965  0.92011  0.93121
r100 0.927    0.92379  0.94324  0.93765  0.93042  0.9211   0.90914
```



1.1.6 Test FF_VFI_AZ_LOOP with Higher Uncertainty

Increase the standard deviation of the Shock.

```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {'savefraccoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {};
```

```

mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 150;
mp_params('it_z_n') = 15;
mp_params('fl_a_max') = 50;
mp_params('st_grid_type') = 'grid_powerspace';
% graph color spectrum
mp_params('cl_colors') = 'copper';

```

Lower standard deviation of shock:

```
% Lower Risk Aversion
mp_params('fl_shk_std') = 0.10;
ff_vfi_az_loop(mp_params, mp_support);
```

Elapsed time is 13.492999 seconds.

xx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xx

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coef
	-	---	----	-----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	2250	150	15	1506.3	0.66947	0.28673	0.4
xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxxxxx										
	c1	c2	c3	c4	c5	c11	c12	c13		
	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0	0.14061	0.1891	0.24154		
r2	0	0	0	0	0	0.1406	0.18908	0.24152		
r3	0	0	0	0	0	0.14053	0.189	0.24142		
r4	0	0	0	0	0	0.14038	0.18881	0.2412		
r5	0	0	0	0	0	0.14013	0.18851	0.24085		
r146	0.93087	0.92957	0.92815	0.92661	0.92492	0.92712	0.92403	0.92069		
r147	0.93121	0.92994	0.92854	0.92702	0.92537	0.92768	0.92465	0.92135		
r148	0.93156	0.9303	0.92893	0.92743	0.92581	0.92823	0.92525	0.92201		
r149	0.93189	0.93065	0.9293	0.92783	0.92623	0.92878	0.92584	0.92264		
r150	0.93222	0.931	0.92967	0.92823	0.92665	0.9293	0.92641	0.92327		

Higher shock standard deviation: low shock high asset save more, high shock more asset save less, high shock low asset save more;

```
% Higher Risk Aversion
mp_params('fl_shk_std') = 0.40;
ff vfi az loop(mp params, mp support);
```

Elapsed time is 18.680264 seconds.

xx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xx

r1	0	0	0	0	0	0.53612	0.59853	0.67884
r2	0	0	0	0	0	0.53609	0.5985	0.67882
r3	0	0	0	0	0	0.53594	0.59839	0.67873
r4	0	0	0	0	0	0.53563	0.59814	0.67853
r5	0	0	0	0	0	0.53511	0.59774	0.67821
r146	0.92696	0.9262	0.92513	0.92359	0.92142	0.91653	0.9078	0.88992
r147	0.92721	0.92647	0.92541	0.9239	0.92176	0.91741	0.90895	0.89144
r148	0.92746	0.92673	0.92569	0.92421	0.9221	0.91827	0.91007	0.87813
r149	0.9277	0.92698	0.92596	0.9245	0.92243	0.9191	0.89605	0.86507
r150	0.92794	0.92724	0.92623	0.9248	0.92276	0.90467	0.88233	0.85227

1.2 FF_VFI_AZ_VEC Savings Vectorized Grid Examples

Go back to fan's MEconTools Toolbox ([bookdown](#)), Matlab Code Examples Repository ([bookdown](#)), or Math for Econ with Matlab Repository ([bookdown](#)).

This is the example vignette for function: `ff_vfi_az_vec` from the **MEconTools Package**. This function solves the dynamic programming problem for a (a,z) model. Households can save a, and face AR(1) shock z. The problem is solved over the infinite horizon.

This is the **vectorized** code, its speed is much faster than the looped code. The function is designed to have small memory footprint and requires low computing resources, yet is fast.

The code uses **common grid**, with the same state space and choice space grids. `ff_vfi_az_bisec_vec` from the **MEconTools Package** solves the same problem but using continuous exact percentage asset choices, which is more precise than the solution here, and perhaps a little bit slower and relies on First Order Conditions. The `ff_vfi_az_mzoom_vec` also solves the same class of problems with continuous exact percentage asset choices, and does not rely on First Order Conditions, but is slower than `ff_vfi_az_bisec_vec`.

Links to Other Code:

Core Savings/Borrowing Dynamic Programming Solution Functions that are functions in the **MEconTools Package**. :

- Common Choice and States Grid : [ff_vfi_az_loop](#)
- Common Choice and States Grid : [ff_vfi_az_vec](#)
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand, rely on FOC, :[ff_vfi_az_bisec_loop](#)
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand, rely on FOC : [ff_vfi_az_bisec_vec](#)
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand, VALUE comparison, :[ff_vfi_az_mzoom_loop](#)
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand, VALUE comparison, : [ff_vfi_az_mzoom_vec](#)

1.2.1 Test FF_VFI_AZ_VEC Defaults

Call the function with defaults. By default, shows the asset policy function summary. Model parameters can be changed by the mp_params.

```
%mp_params
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('fl_crta') = 1.5;
mp_params('fl_beta') = 0.94;
ff_vfi_az_vec(mp_params);
```

Elapsed time is 0.136223 seconds.

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

```
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
```

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefvari	min
	-	---	----	-----	----	----	-----	-----	-----	-----	-----
ap	1	1	2	700	100	7	9855.1	14.079	14.408	1.0234	0

```
xxx TABLE:ap xxxxxxxxxxxxxxxxxxxxxxxx
```

	c1	c2	c3	c4	c5	c6	c7
	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0.045213	0.25576	0.61095	1.0362
r2	0	0	0	0.045213	0.25576	0.61095	1.0362
r3	0	0	0	0.045213	0.25576	0.61095	1.0362
r4	0	0	0	0.06647	0.25576	0.61095	1.0362
r5	0	0	0	0.06647	0.25576	0.61095	1.164
r96	43.924	43.924	43.924	43.924	43.924	45.102	45.102
r97	45.102	45.102	45.102	45.102	45.102	46.298	46.298
r98	46.298	46.298	46.298	46.298	46.298	47.513	47.513
r99	47.513	47.513	47.513	47.513	47.513	48.747	48.747
r100	48.747	48.747	48.747	48.747	48.747	50	50

1.2.2 Test FF_VFI_AZ_BISEC_VEC Speed Tests

Call the function with different a and z grid size, print out speed:

```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_timer') = true;
mp_support('ls_ffcmd') = {};
% A grid 50, shock grid 5:
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 50;
mp_params('it_z_n') = 5;
ff_vfi_az_vec(mp_params, mp_support);
```

Elapsed time is 0.025309 seconds.

```
% A grid 750, shock grid 15:
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 750;
mp_params('it_z_n') = 15;
ff_vfi_az_vec(mp_params, mp_support);
```

Elapsed time is 4.855482 seconds.

```
% A grid 600, shock grid 45:
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 600;
mp_params('it_z_n') = 45;
ff_vfi_az_vec(mp_params, mp_support);
```

Elapsed time is 12.201130 seconds.

1.2.3 Test FF_VFI_AZ_VEC Control Outputs

Run the function first without any outputs, but only the timer.

```
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 50;
```

```

mp_params('it_z_n') = 5;
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_timer') = true;
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {};
ff_vfi_az_vec(mp_params, mp_support);

```

Elapsed time is 0.022504 seconds.

Run the function and show policy function for savings choice. For ls_ffcmd, ls_ffsna, ls_ffgrh, can include these: 'v', 'ap', 'c', 'y', 'coh', 'savefraccoh'. These are value, a prime savings choice, consumption, income, cash on hand, and savings fraction as cash-on-hand.

```

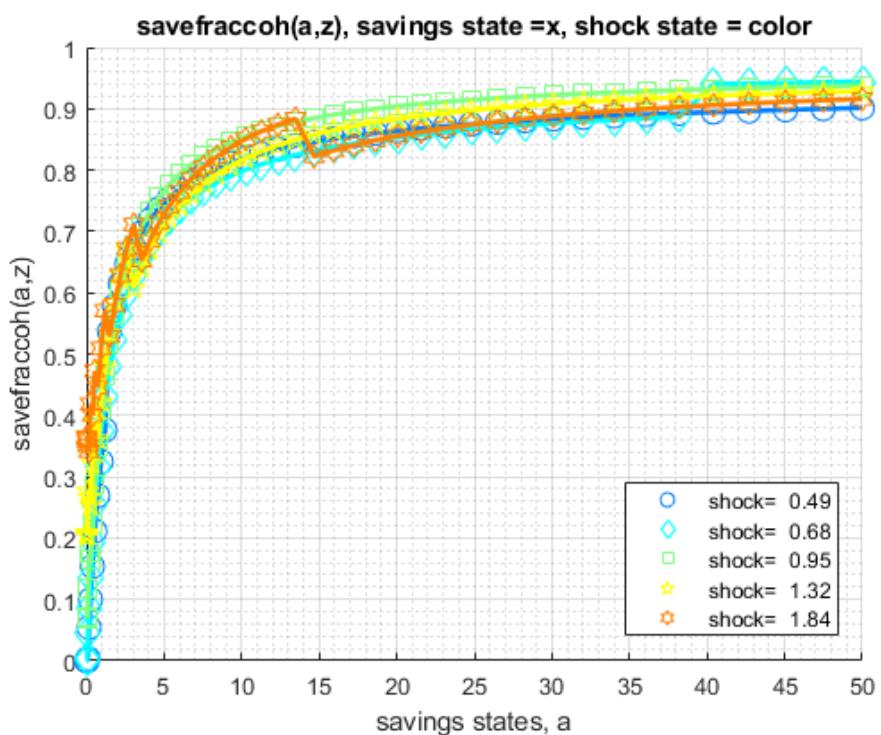
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
% ls_ffcmd: summary print which outcomes
mp_support('ls_ffcmd') = {};
% ls_ffsna: detail print which outcomes
mp_support('ls_ffsna') = {'savefraccoh'};
% ls_ffgrh: graphical print which outcomes
mp_support('ls_ffgrh') = {'savefraccoh'};
ff_vfi_az_vec(mp_params, mp_support);

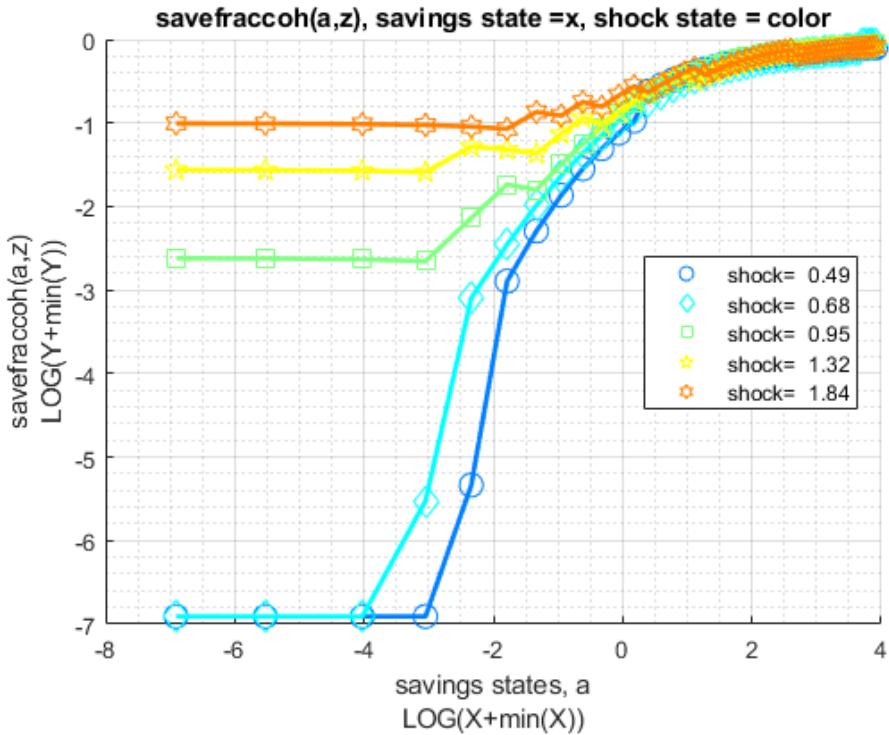
```

Elapsed time is 0.041571 seconds.

group	a	mean_z_0_4858	mean_z_0_67798	mean_z_0_9462	mean_z_1_3205	mean_z
1	0	0	0	0.071865	0.20862	0.3
2	0.002975	0	0	0.071698	0.20827	0.3
3	0.016829	0	0	0.070928	0.20666	0.3
4	0.046375	0	0.0029827	0.069341	0.20331	0.3
5	0.095198	0.0038183	0.044243	0.11681	0.27649	0.3
6	0.1663	0.054362	0.084837	0.17517	0.26637	0.3
7	0.26234	0.099899	0.13609	0.16422	0.25383	0.4
8	0.38568	0.15381	0.19428	0.22348	0.32132	0.4
9	0.53852	0.21153	0.25554	0.28573	0.39055	0.4
10	0.72291	0.26934	0.31659	0.34814	0.36175	0.4
11	0.94076	0.3247	0.37504	0.40848	0.42229	0.5
12	1.1939	0.37617	0.42941	0.46521	0.4802	0.5
13	1.484	0.53695	0.47898	0.51743	0.5344	0
14	1.8128	0.57847	0.52356	0.56473	0.58429	0.5
15	2.1817	0.61468	0.56329	0.6071	0.62958	0.6
16	2.5924	0.6462	0.5985	0.64475	0.67028	0.6
17	3.0463	0.67365	0.62963	0.67804	0.60721	0.7
18	3.5449	0.69762	0.65713	0.70737	0.6404	0.6
19	4.0894	0.71859	0.68142	0.73318	0.67021	0.6
20	4.6813	0.73701	0.70293	0.75587	0.6969	0.7
21	5.3218	0.75325	0.722	0.77584	0.72078	0.7
22	6.0121	0.76763	0.73895	0.79344	0.74211	0.7
23	6.7536	0.7804	0.75407	0.80897	0.76119	0.7
24	7.5474	0.7918	0.76759	0.8227	0.77824	0.8
25	8.3948	0.80201	0.77972	0.83486	0.79351	0.8
26	9.2967	0.81119	0.79063	0.84567	0.80719	0.8
27	10.254	0.81947	0.80049	0.8553	0.81948	0.8
28	11.269	0.82697	0.80941	0.86389	0.83053	0.8
29	12.342	0.83379	0.81752	0.87159	0.84048	0.8

30	13.473	0.84001	0.8249	0.87849	0.84946	0.8
31	14.665	0.84569	0.83165	0.8847	0.85759	0.8
32	15.918	0.8509	0.83782	0.8903	0.86495	0.8
33	17.233	0.8557	0.8435	0.89536	0.87163	0.8
34	18.611	0.86012	0.84872	0.89995	0.8777	0.8
35	20.053	0.86421	0.85354	0.90411	0.88324	0.8
36	21.56	0.86799	0.858	0.9079	0.8883	0.8
37	23.133	0.87151	0.86214	0.91136	0.89292	0.8
38	24.773	0.87479	0.86598	0.91452	0.89716	0.8
39	26.481	0.87784	0.86955	0.91741	0.90105	0.8
40	28.258	0.8807	0.87289	0.92007	0.90463	0.8
41	30.104	0.88337	0.87601	0.92251	0.90793	0.8
42	32.021	0.88588	0.87893	0.92475	0.91097	0.
43	34.01	0.88824	0.88166	0.92683	0.91378	0.8
44	36.07	0.89046	0.88423	0.92874	0.91638	0.8
45	38.204	0.89256	0.88665	0.93052	0.91879	0.9
46	40.412	0.89453	0.9403	0.93216	0.92102	0.9
47	42.695	0.8964	0.94141	0.93368	0.9231	0.9
48	45.053	0.89817	0.94245	0.9351	0.92504	0.9
49	47.488	0.89985	0.94341	0.93642	0.92684	0.
50	50	0.90144	0.9443	0.93765	0.92853	0.9





Run the function and show summaries for savings and fraction of coh saved:

```
mp_params('it_a_n') = 100;
mp_params('it_z_n') = 9;
mp_support('ls_ffcmd') = {'ap', 'savefraccoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {};
mp_support('bl_vfi_store_all') = true; % store c(a,z), y(a,z)
ff_vfi_az_vec(mp_params, mp_support);
```

Elapsed time is 0.230510 seconds.

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coef
	-	---	----	-----	----	----	-----	-----	-----	-----
ap	1	1	2	900	100	9	12904	14.338	14.524	1.
savefraccoh	2	2	2	900	100	9	619.51	0.68834	0.26953	0.39

xxx TABLE:ap xxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6	c7	c8
	-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0.092813	0.25576	0.61095	1.0362
r2	0	0	0	0	0.092813	0.25576	0.61095	1.0362
r3	0	0	0	0	0.092813	0.25576	0.61095	1.0362
r4	0	0	0	0.00051272	0.092813	0.25576	0.61095	1.0362
r5	0	0	0	0.0029004	0.092813	0.25576	0.61095	1.0362
r96	43.924	43.924	43.924	43.924	43.924	45.102	45.102	45.102
r97	45.102	45.102	45.102	45.102	45.102	46.298	46.298	46.298
r98	46.298	46.298	46.298	46.298	46.298	47.513	47.513	47.513
r99	47.513	47.513	47.513	47.513	47.513	48.747	48.747	48.747

r100	48.747	48.747	48.747	48.747	48.747	50	50	50
xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxxxxxxxxx								
	c1	c2	c3	c4	c5	c6	c7	c8
-----	-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0.070073	0.15255	0.28789	0.38573
r2	0	0	0	0	0.070045	0.1525	0.28781	0.38565
r3	0	0	0	0	0.069914	0.15228	0.28748	0.3853
r4	0	0	0	0.00048613	0.069636	0.1518	0.28676	0.38454
r5	0	0	0	0.0027273	0.069182	0.15101	0.28559	0.38329
r96	0.92625	0.92358	0.92022	0.916	0.91072	0.92836	0.91992	0.90945
r97	0.92676	0.92416	0.92088	0.91677	0.91162	0.92918	0.92095	0.91073
r98	0.92727	0.92473	0.92153	0.91752	0.91249	0.92998	0.92194	0.91196
r99	0.92776	0.92528	0.92216	0.91824	0.91333	0.93076	0.92291	0.91315
r100	0.92823	0.92581	0.92277	0.91895	0.91416	0.93151	0.92384	0.91431

1.2.4 Test FF_VFI_AZ_VEC Change Interest Rate and Discount

Show only save fraction of cash on hand:

```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {'savefraccoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {};
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 100;
mp_params('it_z_n') = 7;
mp_params('fl_a_max') = 50;
mp_params('st_grid_type') = 'grid_powerspace';
```

Solve the model with several different interest rates and discount factor:

```
% Lower Savings Incentives
mp_params('fl_beta') = 0.80;
mp_params('fl_r') = 0.01;
ff_vfi_az_vec(mp_params, mp_support);
```

Elapsed time is 0.058079 seconds.

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefva
-----	-	---	----	----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	700	100	7	357.49	0.5107	0.2755	0.5394

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6	c7
-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0	0.0002246	0.041573
r2	0	0	0	0	0	0.00022455	0.041566
r3	0	0	0	0	0	0.0012689	0.041533
r4	0	0	0	0	0	0.001266	0.041462
r5	0	0	0	0	0	0.0034759	0.041345
r96	0.78455	0.78145	0.79995	0.79456	0.7876	0.77865	0.76719

```

r97    0.78669   0.78366   0.77972   0.79679   0.78998   0.78122   0.77001
r98    0.78878   0.78582   0.78197   0.79897   0.79231   0.78374   0.77276
r99    0.79084   0.78794   0.78417   0.77927   0.79459   0.7862    0.77545
r100   0.79285   0.79001   0.78633   0.78154   0.79682   0.7886    0.77808

% Higher Savings Incentives
mp_params('fl_beta') = 0.95;
mp_params('fl_r') = 0.04;
ff_vfi_az_vec(mp_params, mp_support);

Elapsed time is 0.177867 seconds.
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

      i     idx    ndim   numel   rowN   colN     sum   mean    std   coef
      -     ---    ----   -----   ----   ----   -----   -----   -----   -----
savefraccoh  1       1      2      700    100      7    479.94  0.68563  0.27152  0.39

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx
      c1     c2     c3     c4     c5     c6     c7
      ----  -----  -----  -----  -----  -----  -----
r1      0       0      0    0.07007  0.17967  0.30874  0.43404
r2      0       0      0    0.070042 0.17961  0.30866  0.43396
r3      0       0      0    0.069911 0.17935  0.30833  0.4336
r4      0       0      0    0.069633 0.17881  0.30762  0.43284
r5      0       0    0.00049972 0.069179 0.17792  0.30645  0.43158
r96    0.92489  0.92134  0.91672  0.91072  0.92717  0.91691  0.92776
r97    0.92544  0.92198  0.91747  0.91162  0.92802  0.91801  0.92895
r98    0.92598  0.9226   0.9182   0.91249  0.92885  0.91908  0.9301
r99    0.9265   0.9232   0.91891  0.91333  0.92965  0.92011  0.93121
r100   0.927    0.92379  0.9196   0.91416  0.93042  0.9211   0.90914

```

1.2.5 Test FF_VFI_AZ_VEC Changing Risk Aversion

Here, again, show fraction of coh saved in summary tabular form, but also show it graphically.

```

mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {'savefraccoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {'savefraccoh'};
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 100;
mp_params('it_z_n') = 7;
mp_params('fl_a_max') = 50;
mp_params('st_grid_type') = 'grid_powerspace';

```

Solve the model with different risk aversion levels, higher preferences for risk:

```

% Lower Risk Aversion
mp_params('fl_crra') = 0.5;
ff_vfi_az_vec(mp_params, mp_support);

```

Elapsed time is 0.181638 seconds.

```

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

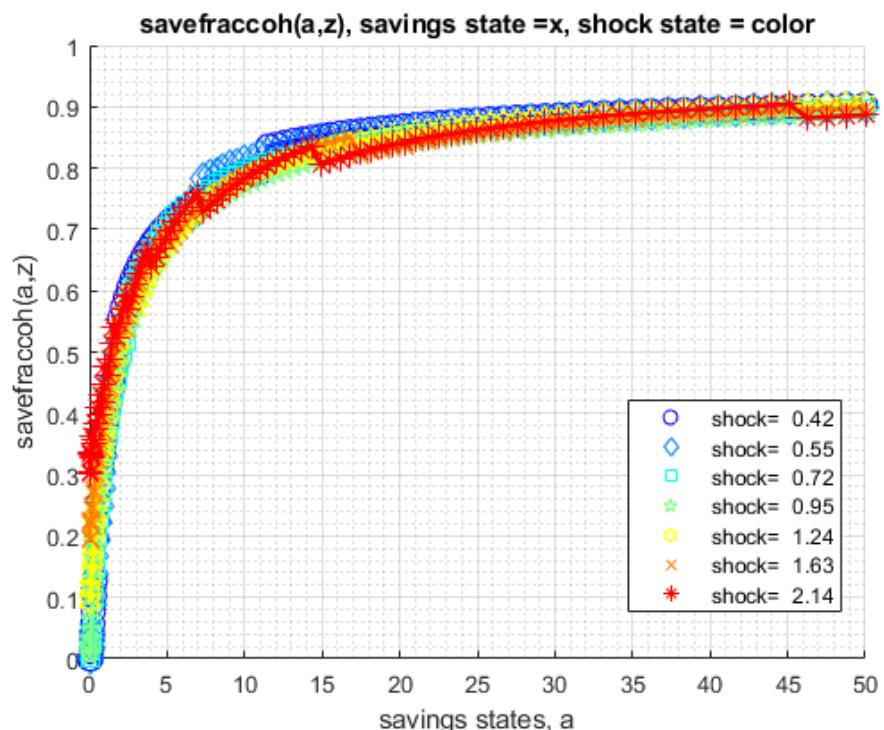
```

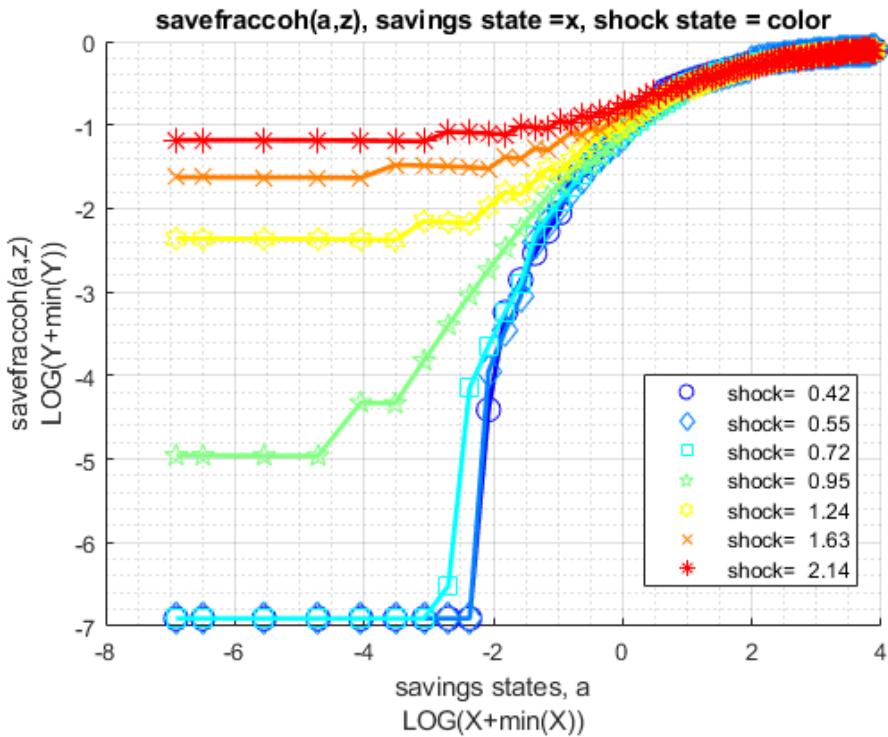
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefv
	-	---	----	-----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	700	100	7	450.35	0.64336	0.2803	0.435

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6	c7
	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0.0060341	0.093241	0.19572	0.30604
r2	0	0	0	0.0060316	0.093213	0.19567	0.30599
r3	0	0	0	0.0060204	0.09308	0.19546	0.30574
r4	0	0	0	0.0059964	0.092798	0.19501	0.3052
r5	0	0	0	0.012229	0.092335	0.19427	0.30431
r96	0.90049	0.89703	0.89253	0.88669	0.90296	0.89297	0.90379
r97	0.90128	0.89791	0.89351	0.88781	0.90404	0.89429	0.88181
r98	0.90205	0.89876	0.89447	0.88891	0.9051	0.89557	0.88337
r99	0.9028	0.89959	0.89541	0.88998	0.90612	0.89681	0.88489
r100	0.90354	0.9004	0.89632	0.89101	0.90711	0.89802	0.88636





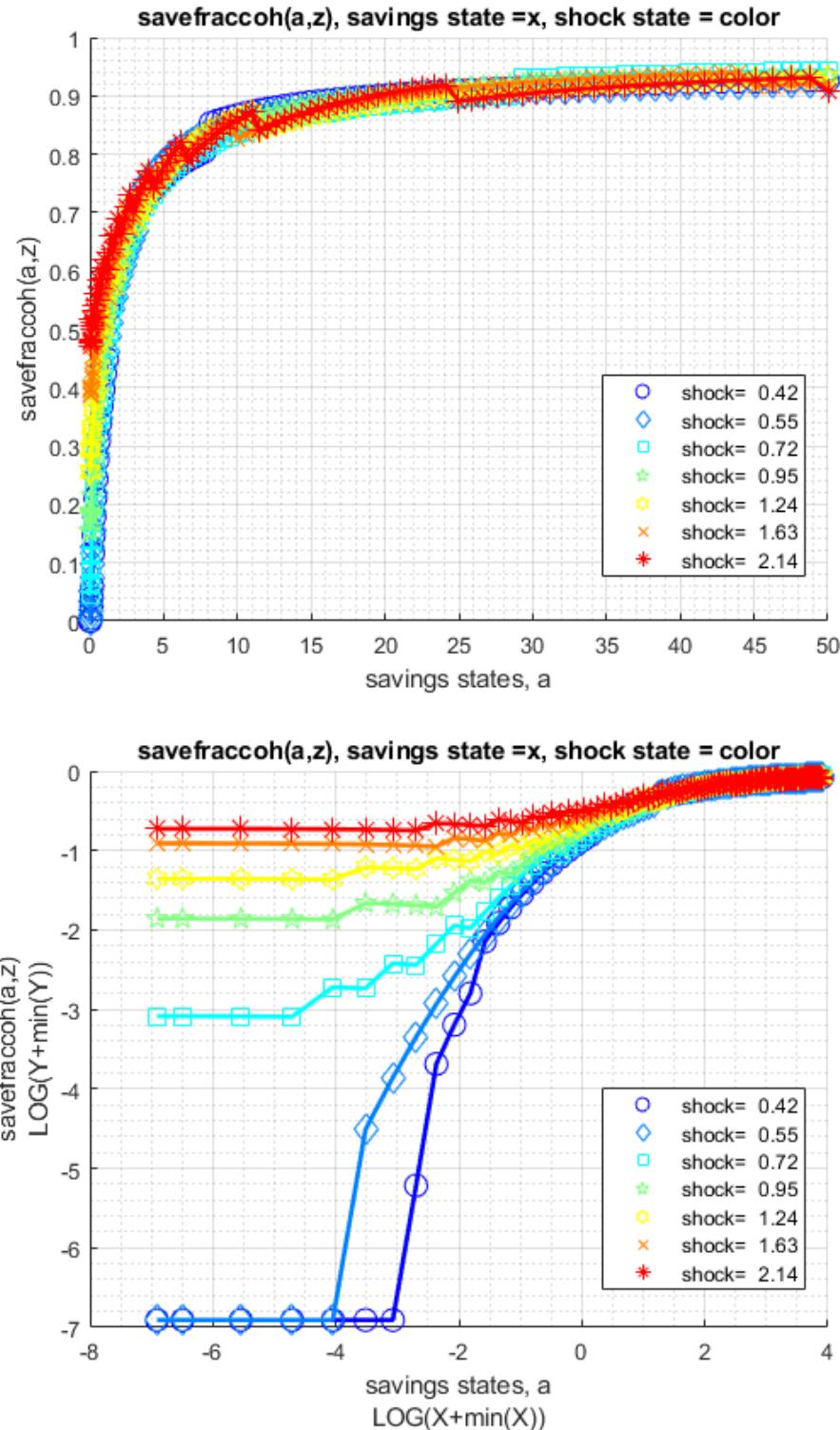
When risk aversion increases, at every state-space point, the household wants to save more.

```
% Higher Risk Aversion
mp_params('fl_crra') = 5;
ff_vfi_az_vec(mp_params, mp_support);

Elapsed time is 0.152901 seconds.
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

      i    idx   ndim   numel   rowN   colN   sum   mean   std   coef
      -    ---   ----   -----   ----   ----   ----   ----   ----   ----
savefraccoh  1     1     2     700    100     7  500.59  0.71513  0.25488  0.35

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx
      c1      c2      c3      c4      c5      c6      c7
      ----  -----
r1      0      0  0.044811  0.15534  0.25694  0.40177  0.48276
r2      0      0  0.044787  0.15528  0.25686  0.40168  0.48268
r3      0      0  0.044678  0.15499  0.2565   0.40124  0.48228
r4      0      0  0.044445  0.15437  0.25572  0.40032  0.48143
r5      0      0  0.064784  0.15337  0.25445  0.39879  0.48003
r96  0.92489  0.92134  0.94129  0.93513  0.92717  0.91691  0.92776
r97  0.92544  0.92198  0.9418   0.9358   0.92802  0.91801  0.92895
r98  0.92598  0.9226   0.9423   0.93644  0.92885  0.91908  0.9301
r99  0.9265   0.9232   0.94278  0.93706  0.92965  0.92011  0.93121
r100 0.927    0.92379  0.94324  0.93765  0.93042  0.9211   0.90914
```



1.2.6 Test FF_VFI_AZ_VEC with Higher Uncertainty

Increase the standard deviation of the Shock.

```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {'savefracoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {};
```

```

mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 150;
mp_params('it_z_n') = 15;
mp_params('fl_a_max') = 50;
mp_params('st_grid_type') = 'grid_powerspace';
% graph color spectrum
mp_params('cl_colors') = 'copper';

```

Lower standard deviation of shock:

```
% Lower Risk Aversion
mp_params('fl_shk_std') = 0.10;
ff_vfi_az_vec(mp_params, mp_support);
```

Elapsed time is 0.544499 seconds.

xx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xx

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coef
	-	---	----	-----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	2250	150	15	1506.3	0.66947	0.28673	0.4
xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxxxxxxxx										
	c1	c2	c3	c4	c5	c11	c12	c13		
	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0	0.14061	0.1891	0.24154		
r2	0	0	0	0	0	0.1406	0.18908	0.24152		
r3	0	0	0	0	0	0.14053	0.189	0.24142		
r4	0	0	0	0	0	0.14038	0.18881	0.2412		
r5	0	0	0	0	0	0.14013	0.18851	0.24085		
r146	0.93087	0.92957	0.92815	0.92661	0.92492	0.92712	0.92403	0.92069		
r147	0.93121	0.92994	0.92854	0.92702	0.92537	0.92768	0.92465	0.92135		
r148	0.93156	0.9303	0.92893	0.92743	0.92581	0.92823	0.92525	0.92201		
r149	0.93189	0.93065	0.9293	0.92783	0.92623	0.92878	0.92584	0.92264		
r150	0.93222	0.931	0.92967	0.92823	0.92665	0.9293	0.92641	0.92327		

Higher shock standard deviation: low shock high asset save more, high shock more asset save less, high shock low asset save more;

```
% Higher Risk Aversion
mp_params('f1_shk_std') = 0.40;
ff vfi az vec(mp_params, mp_support);
```

Elapsed time is 0.515060 seconds.

xx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xx

r1	0	0	0	0	0	0.53612	0.59853	0.67884
r2	0	0	0	0	0	0.53609	0.5985	0.67882
r3	0	0	0	0	0	0.53594	0.59839	0.67873
r4	0	0	0	0	0	0.53563	0.59814	0.67853
r5	0	0	0	0	0	0.53511	0.59774	0.67821
r146	0.92696	0.9262	0.92513	0.92359	0.92142	0.91653	0.9078	0.88992
r147	0.92721	0.92647	0.92541	0.9239	0.92176	0.91741	0.90895	0.89144
r148	0.92746	0.92673	0.92569	0.92421	0.9221	0.91827	0.91007	0.87813
r149	0.9277	0.92698	0.92596	0.9245	0.92243	0.9191	0.89605	0.86507
r150	0.92794	0.92724	0.92623	0.9248	0.92276	0.90467	0.88233	0.85227

1.3 FF_VFI_AZ_BISEC_LOOP Savings Loop Exact (FOC) Examples

Go back to [fan's MEconTools Toolbox \(bookdown\)](#), [Matlab Code Examples Repository \(bookdown\)](#), or [Math for Econ with Matlab Repository \(bookdown\)](#).

This is the example vignette for function:[`ff_vfi_az_bisec_loop`](#)from the [MEconTools Package](#). This function solves the dynamic programming problem for a (a,z) model. Households can save a, and face AR(1) shock z. The problem is solved over the infinite horizon.

This is the **looped** code, it is slow for larger state-space problems.

The code uses **continuous** choices, solved with bisection. The state-space is on a grid, but choice grids are in terms of **percentage of resources** to save and solved exactly.

Links to Other Code:

Core Savings/Borrowing Dynamic Programming Solution Functions that are functions in the [MEconTools Package](#) :

- Common Choice and States Grid : [`ff_vfi_az_loop`](#)
- Common Choice and States Grid : [`ff_vfi_az_vec`](#)
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand, rely on FOC, :[`ff_vfi_az_bisec_loop`](#)
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand, rely on FOC : [`ff_vfi_az_bisec_vec`](#)
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand, VALUE comparison, :[`ff_vfi_az_mzoom_loop`](#)
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand, VALUE comparison, :[`ff_vfi_az_mzoom_vec`](#)

1.3.1 Test FF_VFI_AZ_BISEC_LOOP Defaults

Call the function with defaults. By default, shows the asset policy function summary. Model parameters can be changed by the mp_params.

```
%mp_params
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('fl_crra') = 1.5;
mp_params('fl_beta') = 0.94;
% call function
ff_vfi_az_bisec_loop(mp_params);
```

Elapsed time is 33.158577 seconds.

```
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefvari	min
	-	---	----	-----	----	----	-----	-----	-----	-----	-----
ap	1	1	2	700	100	7	9863.4	14.091	14.388	1.0211	0
xxx TABLE:ap xxxxxxxxxxxxxxxxxxxx											
	c1	c2	c3	c4	c5	c6	c7				
	-----	-----	-----	-----	-----	-----	-----				
r1	0	0	0	0.053491	0.25574	0.60604	1.1157				
r2	0	0	0	0.053998	0.25571	0.6066	1.1163				
r3	0	0	0	0.056449	0.25576	0.60907	1.1187				
r4	0	0	0	0.061799	0.26016	0.6109	1.1239				
r5	0	0	0	0.066463	0.26897	0.61141	1.1327				
r96	43.388	43.52	43.701	43.925	44.222	44.68	45.228				
r97	44.566	44.695	44.878	45.103	45.398	45.856	46.403				
r98	45.761	45.892	46.072	46.298	46.592	47.05	47.597				
r99	46.973	47.107	47.286	47.514	47.806	48.263	48.815				
r100	48.206	48.338	48.519	48.746	49.037	49.497	50.117				

1.3.2 Test FF_VFI_AZ_BISEC_LOOP Speed Tests

Call the function with defaults. By default, shows the asset policy function summary. Model parameters can be changed by the mp_params.

```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_timer') = true;
mp_support('ls_ffcmd') = {};
% A grid 50, shock grid 5:
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 50;
mp_params('it_z_n') = 5;
ff_vfi_az_bisec_loop(mp_params, mp_support);
```

Elapsed time is 14.819629 seconds.

```
% A grid 750, shock grid 15:
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 750;
mp_params('it_z_n') = 15;
ff_vfi_az_bisec_loop(mp_params, mp_support);
```

Elapsed time is 783.169420 seconds.

```
%A grid 600, shock grid 45:
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 600;
mp_params('it_z_n') = 45;
ff_vfi_az_bisec_loop(mp_params, mp_support);
```

Elapsed time is 1955.142516 seconds.

1.3.3 Test FF_VFI_AZ_BISEC_LOOP Control Outputs

Run the function first without any outputs;

```
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 50;
mp_params('it_z_n') = 5;
```

```

mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_timer') = true;
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {};
ff_vfi_az_vec(mp_params, mp_support);

```

Elapsed time is 0.122166 seconds.

Run the function and show policy function for savings choice. For ls_ffcmd, ls_ffsna, ls_ffgrh, can include these: 'v', 'ap', 'c', 'y', 'coh', 'savefraccoh'. These are value, aprime savings choice, consumption, income, cash on hand, and savings fraction as cash-on-hand.

```

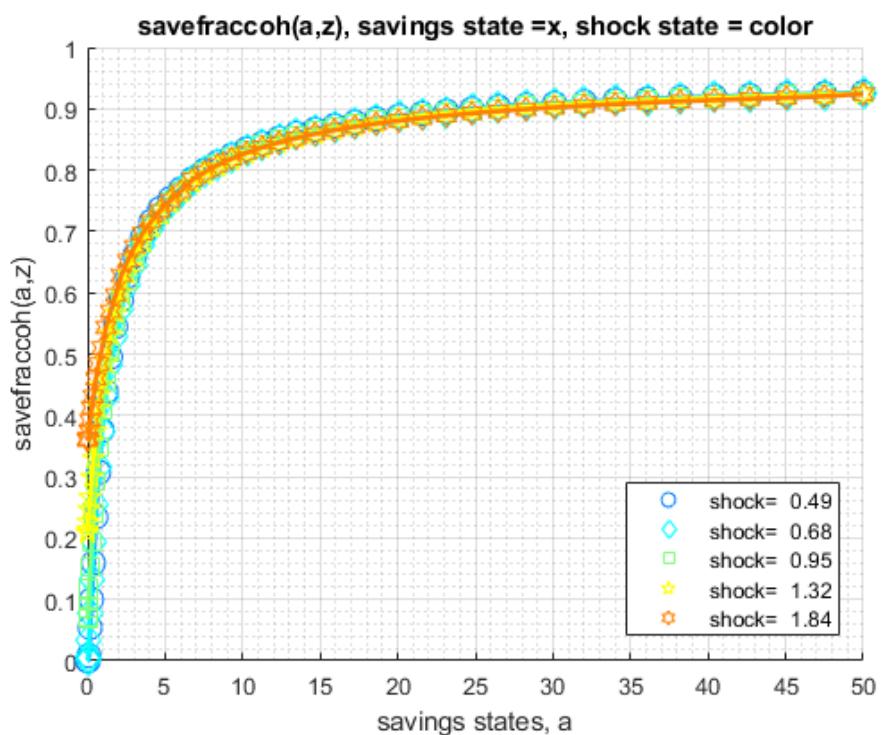
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
% ls_ffcmd: summary print which outcomes
mp_support('ls_ffcmd') = {};
% ls_ffsna: detail print which outcomes
mp_support('ls_ffsna') = {'savefraccoh'};
% ls_ffgrh: graphical print which outcomes
mp_support('ls_ffgrh') = {'savefraccoh'};
ff_vfi_az_bisec_loop(mp_params, mp_support);

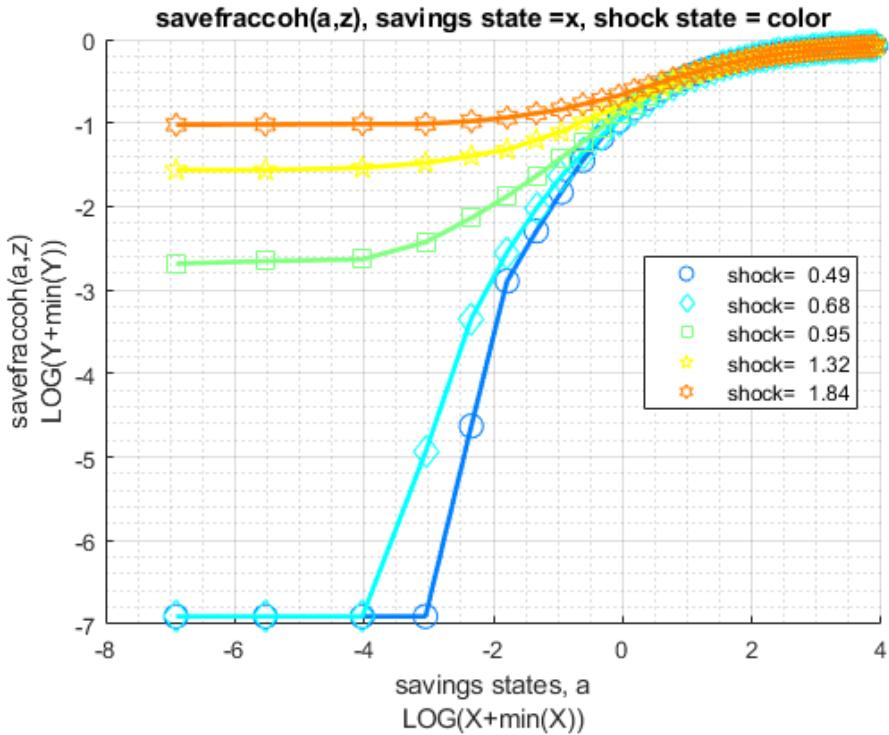
```

Elapsed time is 20.812511 seconds.

group	a	mean_z_0_4858	mean_z_0_67798	mean_z_0_9462	mean_z_1_3205	mean_z
1	0	0	0	0.067239	0.20859	0.3
2	0.002975	0	0	0.069375	0.20829	0.3
3	0.016829	0	0	0.070901	0.2139	0.3
4	0.046375	0	0.0061439	0.087319	0.2266	0.3
5	0.095198	0.0087684	0.034403	0.1168	0.2468	0.3
6	0.1663	0.054361	0.077248	0.1522	0.26639	0.3
7	0.26234	0.099892	0.13132	0.19388	0.29929	0.4
8	0.38568	0.15958	0.19309	0.24112	0.33017	0.4
9	0.53852	0.23417	0.25553	0.29215	0.37436	0.4
10	0.72291	0.3071	0.31656	0.34812	0.41153	0.4
11	0.94076	0.37595	0.37503	0.40842	0.44925	0.5
12	1.1939	0.43881	0.42941	0.45755	0.48697	0.5
13	1.484	0.49509	0.48129	0.50381	0.53262	0.5
14	1.8128	0.54489	0.53018	0.54642	0.56778	0.5
15	2.1817	0.58871	0.57382	0.58548	0.60055	0.
16	2.5924	0.62716	0.61258	0.62076	0.63101	0.6
17	3.0463	0.66079	0.64682	0.65243	0.65884	0.
18	3.5449	0.69027	0.67709	0.68069	0.68423	0.6
19	4.0894	0.71621	0.70376	0.70596	0.70724	0.7
20	4.6813	0.73703	0.72732	0.72848	0.72799	0.7
21	5.3218	0.75326	0.74813	0.7485	0.74673	0.7
22	6.0121	0.76913	0.76657	0.76632	0.76364	0.7
23	6.7536	0.78536	0.78286	0.78231	0.77889	0.
24	7.5474	0.79983	0.79745	0.79653	0.79269	0.7
25	8.3948	0.81271	0.81039	0.80929	0.80514	0.8
26	9.2967	0.82418	0.82198	0.82076	0.81637	0.8
27	10.254	0.8345	0.83242	0.83114	0.82656	0.8
28	11.269	0.84377	0.84176	0.84042	0.83584	0.8
29	12.342	0.85214	0.85024	0.84884	0.8442	0.8
30	13.473	0.85964	0.85781	0.85647	0.85183	0.8

31	14.665	0.86648	0.86471	0.86337	0.85879	0.8
32	15.918	0.87264	0.87099	0.86965	0.86507	0.8
33	17.233	0.87826	0.87667	0.87533	0.87161	0.8
34	18.611	0.88338	0.88186	0.88052	0.87771	0.8
35	20.053	0.88802	0.88656	0.88528	0.88326	0.8
36	21.56	0.8923	0.89089	0.88967	0.88833	0.8
37	23.133	0.89614	0.89486	0.89364	0.8926	0.8
38	24.773	0.89974	0.89852	0.8973	0.89626	0.
39	26.481	0.90304	0.90182	0.90072	0.89968	0.8
40	28.258	0.90603	0.90493	0.90383	0.90279	0.8
41	30.104	0.90884	0.90774	0.9067	0.90572	0.9
42	32.021	0.9114	0.91036	0.90932	0.90841	0.9
43	34.01	0.91378	0.9128	0.91183	0.91091	0.9
44	36.07	0.91598	0.91506	0.91408	0.91317	0.9
45	38.204	0.91805	0.91714	0.91622	0.91537	0.9
46	40.412	0.91994	0.91909	0.91817	0.91732	0.9
47	42.695	0.92171	0.92086	0.92001	0.91921	0.
48	45.053	0.92336	0.92257	0.92171	0.92092	0.9
49	47.488	0.92489	0.92409	0.92336	0.92257	0.9
50	50	0.92629	0.92562	0.92489	0.92428	0.9





Run the function and show summaries for savings and fraction of coh saved:

```
mp_params('it_a_n') = 100;
mp_params('it_z_n') = 9;
mp_support('ls_ffcmd') = {'ap', 'savefraccoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {};
mp_support('bl_vfi_store_all') = true; % store c(a,z), y(a,z)
ff_vfi_az_bisec_loop(mp_params, mp_support);
```

Elapsed time is 57.010652 seconds.

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coef
	-	---	----	-----	----	----	-----	-----	-----	-----
ap	1	1	2	900	100	9	12926	14.362	14.544	1.0
savefraccoh	2	2	2	900	100	9	621.24	0.69027	0.26896	0.38

xxx TABLE:ap xxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6	c7	c8
	-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0.087442	0.27778	0.58243	1.0038
r2	0	0	0	0	0.087962	0.27828	0.58297	1.0044
r3	0	0	0	0	0.090477	0.28074	0.58547	1.0069
r4	0	0	0	0.00055771	0.09279	0.28605	0.5907	1.0122
r5	0	0	0	0.0059496	0.09602	0.29477	0.59952	1.0209
r96	43.845	43.923	44.022	44.198	44.428	44.722	45.103	45.546
r97	45.031	45.101	45.208	45.384	45.613	45.91	46.293	46.735
r98	46.237	46.297	46.411	46.59	46.818	47.115	47.501	47.948
r99	47.46	47.512	47.635	47.812	48.041	48.34	48.726	49.191

r100	48.703	48.746	48.878	49.055	49.283	49.586	49.978	50.495
xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxxxxxxxx								
	c1	c2	c3	c4	c5	c6	c7	c8
-----	-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0.066018	0.16569	0.27445	0.37369
r2	0	0	0	0	0.066384	0.16593	0.27463	0.37381
r3	0	0	0	0	0.068154	0.16715	0.27549	0.37442
r4	0	0	0	0.00052879	0.069619	0.16978	0.27726	0.37564
r5	0	0	0	0.0055946	0.071572	0.17405	0.28025	0.37766
r96	0.92458	0.92354	0.92226	0.92171	0.92116	0.92055	0.91994	0.91842
r97	0.92531	0.92416	0.92306	0.92251	0.92196	0.92141	0.92086	0.91933
r98	0.92605	0.9247	0.92379	0.9233	0.92275	0.9222	0.92171	0.92031
r99	0.92672	0.92525	0.92452	0.92403	0.92348	0.923	0.92251	0.92147
r100	0.92739	0.9258	0.92525	0.92477	0.92422	0.92379	0.92342	0.92336

1.3.4 Test FF_VFI_AZ_BISEC_LOOP Change Interest Rate and Discount

Show only save fraction of cash on hand:

```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {'savefraccoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {};
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 100;
mp_params('it_z_n') = 7;
mp_params('fl_a_max') = 50;
mp_params('st_grid_type') = 'grid_powerspace';
```

Solve the model with several different interest rates and discount factor:

```
% Lower Savings Incentives
mp_params('fl_beta') = 0.80;
mp_params('fl_r') = 0.01;
ff_vfi_az_bisec_loop(mp_params, mp_support);
```

Elapsed time is 10.824225 seconds.

```
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coef
-----	-	---	----	----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	700	100	7	357.85	0.51122	0.27528	0.53

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6	c7
-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0	0.00022362	0.041544
r2	0	0	0	0	0	0.00022362	0.041544
r3	0	0	0	0	0	0.0011391	0.041544
r4	0	0	0	0	0	0.0016884	0.041483
r5	0	0	0	0	0	0.0034584	0.04136
r96	0.79586	0.79275	0.78945	0.78591	0.78225	0.77853	0.77059

```

r97    0.79684    0.79379    0.79055    0.78713    0.78359    0.77993    0.77212
r98    0.79782    0.79482    0.79171    0.78835    0.78488    0.78127    0.77365
r99    0.79873    0.79586    0.79275    0.78951    0.7861     0.78262    0.77548
r100   0.79965    0.79684    0.79385    0.79061    0.78732    0.7839     0.7781

% Higher Savings Incentives
mp_params('fl_beta') = 0.95;
mp_params('fl_r') = 0.04;
ff_vfi_az_bisec_loop(mp_params, mp_support);

Elapsed time is 53.369195 seconds.
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

      i   idx  ndim  numel  rowN  colN  sum  mean  std  coef
      -   ---  ----  -----  ----  ----  ----  -----  -----  -----
savefraccoh  1     1     2     700    100     7  481.37  0.68768  0.27118  0.39

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx
      c1      c2      c3      c4      c5      c6      c7
      -----  -----  -----  -----  -----  -----  -----
r1      0       0       0  0.065774  0.18076  0.30655  0.41654
r2      0       0       0  0.066201  0.18101  0.30674  0.4166
r3      0       0       0  0.06791   0.18223  0.30747  0.41709
r4      0       0       0  0.069619  0.18467  0.30759  0.41812
r5      0       0       0  0.071694  0.18876  0.30838  0.41983
r96    0.92428  0.92245  0.92178  0.92116  0.92049  0.91872  0.91824
r97    0.92501  0.92324  0.92257  0.92196  0.92129  0.91958  0.91921
r98    0.92574  0.92397  0.92336  0.92275  0.92208  0.92049  0.92025
r99    0.92647  0.9247   0.92409  0.92348  0.92287  0.92147  0.92159
r100   0.92702  0.92544  0.92483  0.92422  0.92373  0.92336  0.92348

```

1.3.5 Test FF_VFI_AZ_BISEC_LOOP Changing Risk Aversion

Here, again, show fraction of coh saved in summary tabular form, but also show it graphically.

```

mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {'savefraccoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {'savefraccoh'};
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 100;
mp_params('it_z_n') = 7;
mp_params('fl_a_max') = 50;
mp_params('st_grid_type') = 'grid_powerspace';

```

Solve the model with different risk aversion levels, higher preferences for risk:

```

% Lower Risk Aversion
mp_params('fl_crra') = 0.5;
ff_vfi_az_bisec_loop(mp_params, mp_support);

```

Elapsed time is 47.635241 seconds.

```

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

```

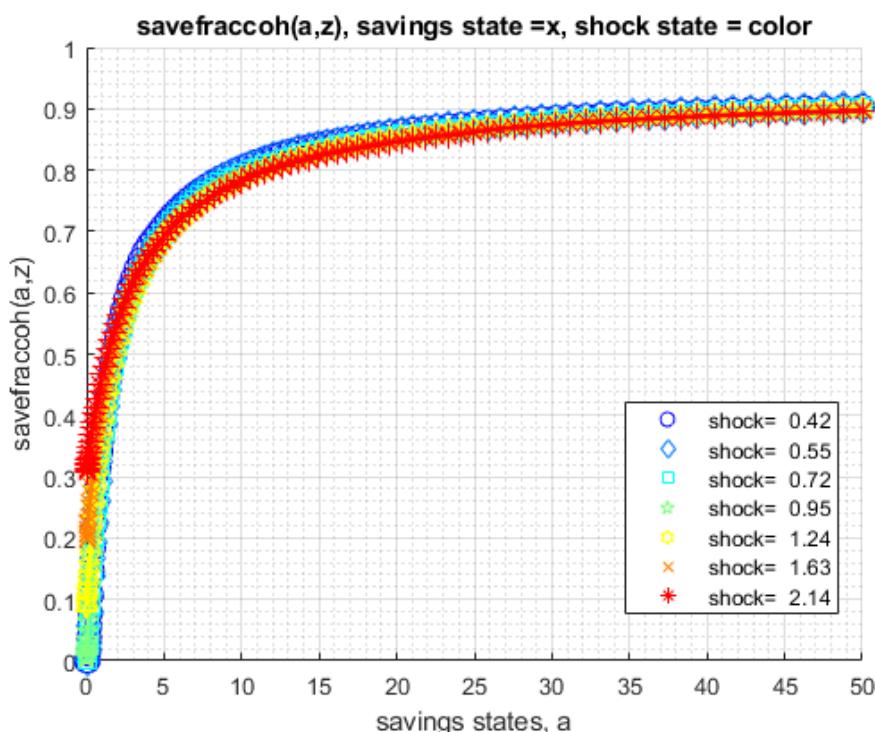
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)

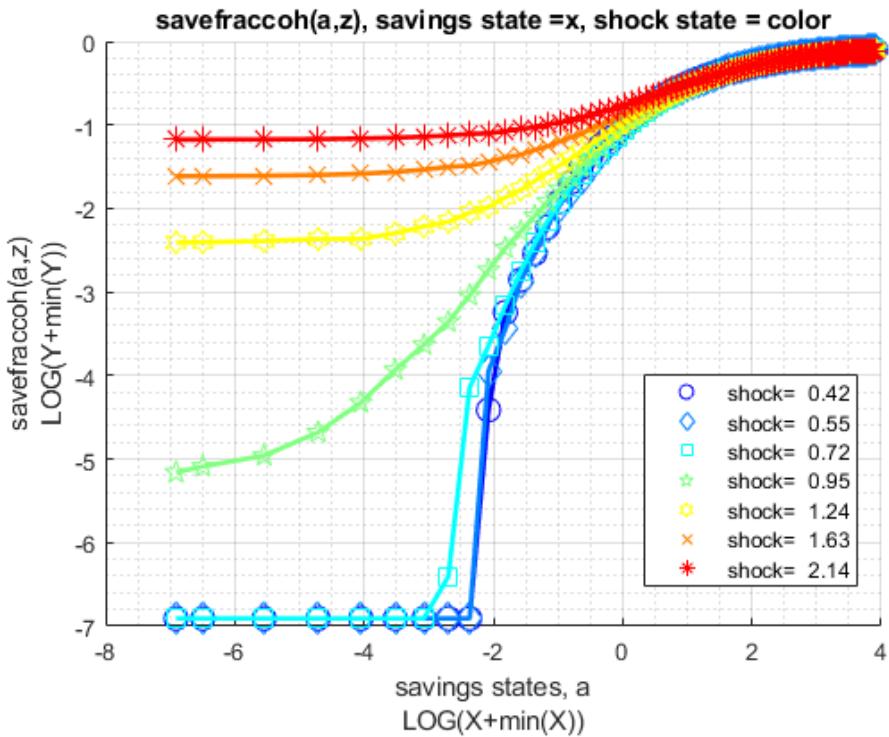
xx

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefv
	-	---	----	-----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	700	100	7	452.13	0.6459	0.28031	0.433

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6	c7
	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0.0047401	0.089089	0.19822	0.30783
r2	0	0	0	0.0051674	0.089394	0.1984	0.30796
r3	0	0	0	0.0060218	0.090676	0.19926	0.30851
r4	0	0	0	0.0082801	0.092812	0.20115	0.30973
r5	0	0	0	0.012247	0.092995	0.2042	0.31174
r96	0.90047	0.89925	0.89828	0.8973	0.89632	0.89376	0.89297
r97	0.90127	0.90017	0.89919	0.89828	0.8973	0.8948	0.89394
r98	0.90206	0.90102	0.90011	0.89919	0.89828	0.89577	0.89498
r99	0.90279	0.90188	0.90102	0.90011	0.89919	0.89681	0.8959
r100	0.90359	0.90273	0.90188	0.90096	0.90011	0.89803	0.89687





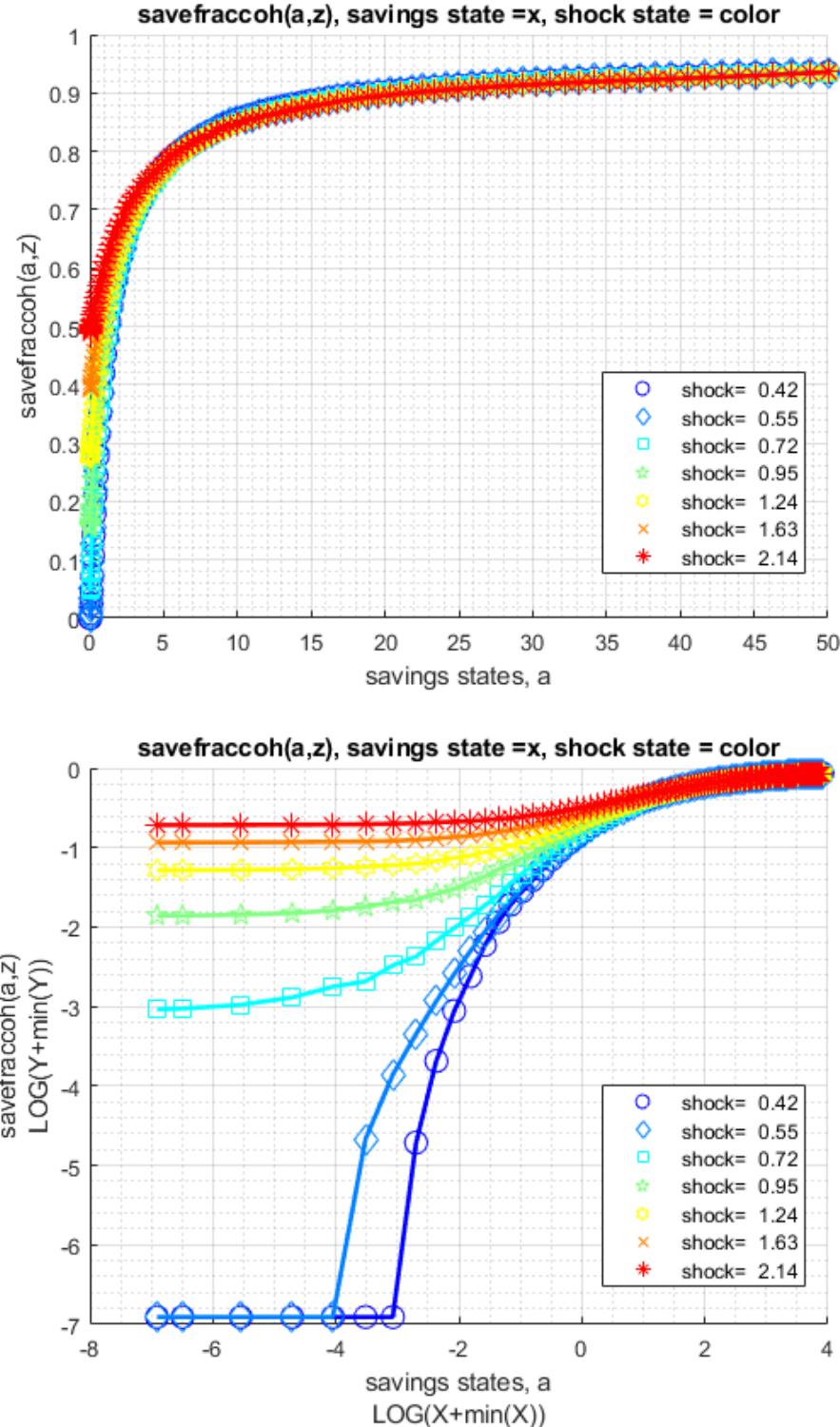
When risk aversion increases, at every state-space point, the household wants to save more.

```
% Higher Risk Aversion
mp_params('fl_crra') = 5;
ff_vfi_az_bisec_loop(mp_params, mp_support);

Elapsed time is 46.937845 seconds.
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

      i    idx   ndim   numel   rowN   colN   sum   mean   std   coef
      -    ---   ----   -----   ----   ----   ----   ----   ----   ----
savefraccoh  1     1     2     700    100     7  502.71  0.71816  0.25437  0.3

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx
      c1      c2      c3      c4      c5      c6      c7
      ----  -----
r1      0      0  0.047037  0.15537  0.27573  0.3909  0.48782
r2      0      0  0.047525  0.15531  0.27591  0.39102 0.48795
r3      0      0  0.049844  0.1569   0.27695  0.3917  0.48837
r4      0      0  0.054788  0.16025  0.27915  0.3931  0.48929
r5      0      0  0.062905  0.16569  0.28275  0.39542 0.49075
r96  0.93307  0.93258  0.93203  0.93154  0.9302  0.92995 0.92971
r97  0.93374  0.93325  0.93276  0.93227  0.93111 0.93105 0.93117
r98  0.93441  0.93398  0.93349  0.93307  0.93209 0.93227 0.9327
r99  0.93508  0.93465  0.93423  0.93392  0.93331 0.93368 0.93435
r100 0.93575  0.93539  0.93508  0.9349   0.93496 0.93526 0.93587
```



1.3.6 Test FF_VFI_AZ_BISEC_LOOP with Higher Uncertainty

Increase the standard deviation of the Shock.

```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {'savefraccoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {};
```

```

mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 150;
mp_params('it_z_n') = 15;
mp_params('fl_a_max') = 50;
mp_params('st_grid_type') = 'grid_powerspace';
% graph color spectrum
mp_params('cl_colors') = 'copper';

```

Lower standard deviation of shock:

```
% Lower Risk Aversion
mp_params('fl_shk_std') = 0.10;
ff_vfi_az_bisection(mp_params, mp_support);
```

Elapsed time is 150.979328 seconds.

xx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xx

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coef
	-	---	----	-----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	2250	150	15	1507.5	0.67001	0.28668	0.42
xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxxxxxxxx										
	c1	c2	c3	c4	c5	c11	c12	c13		
	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0	0.13847	0.18485	0.23026		
r2	0	0	0	0	0	0.13853	0.18491	0.23032		
r3	0	0	0	0	0	0.13895	0.18528	0.23063		
r4	0	0	0	0	0	0.13987	0.18607	0.2313		
r5	0	0	0	0	0	0.14011	0.18735	0.2324		
r146	0.92373	0.92354	0.9233	0.92312	0.92287	0.92086	0.92068	0.92049		
r147	0.92422	0.92403	0.92385	0.92361	0.92342	0.92141	0.92123	0.92098		
r148	0.9247	0.92452	0.92434	0.92409	0.92391	0.9219	0.92171	0.92153		
r149	0.92519	0.92501	0.92483	0.92458	0.9244	0.92245	0.92226	0.92208		
r150	0.92568	0.9255	0.92531	0.92507	0.92489	0.92293	0.92275	0.92257		

Higher shock standard deviation: low shock high asset save more, high shock more asset save less, high shock low asset save more;

```
% Higher Risk Aversion
mp_params('fl_shk_std') = 0.40;
ff vfi az biseq loop(mp params, mp support);
```

Elapsed time is 136.803951 seconds.

xx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xx

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coef
	-	---	----	-----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	2250	150	15	1685.6	0.74914	0.22909	0.3
xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxxxxxxxx										
	c1	c2	c3	c4	c5	c11	c12	c13		

r1	0	0	0	0	0	0.5264	0.61264	0.68271
r2	0	0	0	0	0	0.52646	0.61264	0.68271
r3	0	0	0	0	0	0.52658	0.6127	0.68271
r4	0	0	0	0	0	0.52682	0.61288	0.68283
r5	0	0	0	0	0	0.52731	0.61313	0.68295
r146	0.92983	0.92928	0.92873	0.92806	0.92739	0.92269	0.92354	0.9258
r147	0.9302	0.92971	0.9291	0.92849	0.92788	0.92361	0.92477	0.9269
r148	0.93056	0.93008	0.92953	0.92892	0.92831	0.92458	0.92593	0.928
r149	0.93093	0.93044	0.92995	0.92934	0.92873	0.9258	0.92702	0.9291
r150	0.9313	0.93087	0.93032	0.92977	0.92916	0.92696	0.92818	0.93014

1.4 FF_VFI_AZ_BISEC_VEC Savings Vectorized Exact (FOC) Examples

Go back to fan's MEconTools Toolbox ([bookdown](#)), Matlab Code Examples Repository ([bookdown](#)), or Math for Econ with Matlab Repository ([bookdown](#)).

This is the example vignette for function: `ff_vfi_az_bisec_vec` from the [MEconTools Package](#). This function solves the dynamic programming problem for a (a,z) model. Households can save a, and face AR(1) shock z. The problem is solved over the infinite horizon.

This is the vectorized code, its speed is much faster than the looped code. The function is designed to have small memory footprint and requires low computing resources, yet is fast.

The code uses **continuous choices**, solved with bi(multi)section. The state-space is on a grid, but choice grids are in terms of percentage of resources available, which is individual specific, to save and solved exactly up to $((1/(2)^{16})^*100=0.001525878)$ percentage of cash on hand. The `ff_vfi_az_vec` from the [MEconTools Package](#) solves the same problem using vectorized common grid code where the choice set and state space share the same grid. The common grid function is faster, but less precise for the same number of asset grid points.

Links to Other Code:

Core Savings/Borrowing Dynamic Programming Solution Functions that are functions in the [MEconTools Package](#) :

- Common Choice and States Grid : [ff_vfi_az_loop](#)
- Common Choice and States Grid : [ff_vfi_az_vec](#)
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand, rely on FOC, :[ff_vfi_az_bisec_loop](#)
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand, rely on FOC : [ff_vfi_az_bisec_vec](#)
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand, VALUE comparison, :[ff_vfi_az_mzoom_loop](#)
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand, VALUE comparison, : [ff_vfi_az_mzoom_vec](#)

1.4.1 Test FF_VFI_AZ_BISEC_VEC Defaults

Call the function with defaults. By default, shows the asset policy function summary. Model parameters can be changed by the mp_params.

```
%mp_params
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('fl_crra') = 1.5;
mp_params('fl_beta') = 0.94;
% call function
ff_vfi_az_bisec_vec(mp_params);
```

Elapsed time is 1.762201 seconds.

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefvari	min
	-	--	---	-----	----	----	-----	-----	-----	-----	-----
ap	1	1	2	700	100	7	9863.4	14.091	14.388	1.0211	0

xxx TABLE:ap xxxxxxxxxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6	c7
	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0.053491	0.25574	0.60604	1.1157
r2	0	0	0	0.053998	0.25571	0.6066	1.1163
r3	0	0	0	0.056449	0.25576	0.60907	1.1187
r4	0	0	0	0.061799	0.26016	0.6109	1.1239
r5	0	0	0	0.066463	0.26897	0.61141	1.1327
r96	43.388	43.52	43.701	43.925	44.222	44.68	45.228
r97	44.566	44.695	44.878	45.103	45.398	45.856	46.403
r98	45.761	45.892	46.072	46.298	46.592	47.05	47.597
r99	46.973	47.107	47.286	47.514	47.806	48.263	48.815
r100	48.206	48.338	48.519	48.746	49.037	49.497	50.117

1.4.2 Test FF_VFI_AZ_BISEC_VEC Speed Tests

Call the function with defaults. By default, shows the asset policy function summary. Model parameters can be changed by the mp_params.

```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_timer') = true;
mp_support('ls_ffcmd') = {};
% A grid 50, shock grid 5:
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 50;
mp_params('it_z_n') = 5;
ff_vfi_az_bisec_vec(mp_params, mp_support);
```

Elapsed time is 0.792541 seconds.

```
% A grid 750, shock grid 15:
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 750;
mp_params('it_z_n') = 15;
ff_vfi_az_bisec_vec(mp_params, mp_support);
```

Elapsed time is 43.095190 seconds.

```
% A grid 600, shock grid 45:
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 600;
mp_params('it_z_n') = 45;
ff_vfi_az_bisec_vec(mp_params, mp_support);
```

Elapsed time is 80.139775 seconds.

1.4.3 Test FF_VFI_AZ_BISEC_VEC Control Outputs

Run the function first without any outputs;

```
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 50;
mp_params('it_z_n') = 5;
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_timer') = true;
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {};
ff_vfi_az_vec(mp_params, mp_support);
```

Elapsed time is 0.029901 seconds.

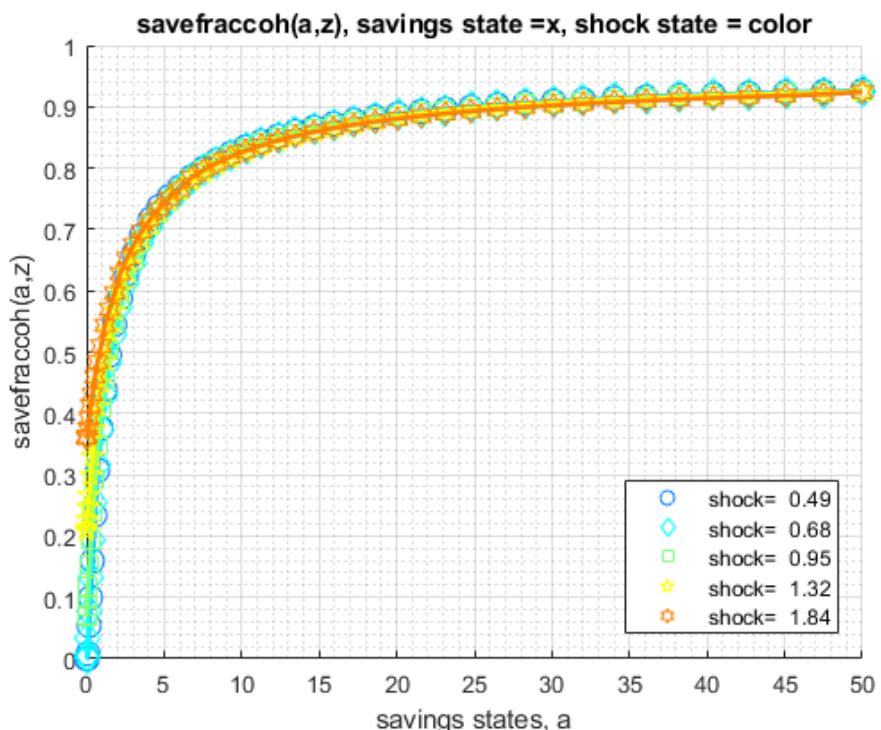
Run the function and show policy function for savings choice. For ls_ffcmd, ls_ffsna, ls_ffgrh, can include these: 'v', 'ap', 'c', 'y', 'coh', 'savefraccoh'. These are value, aprime savings choice, consumption, income, cash on hand, and savings fraction as cash-on-hand.

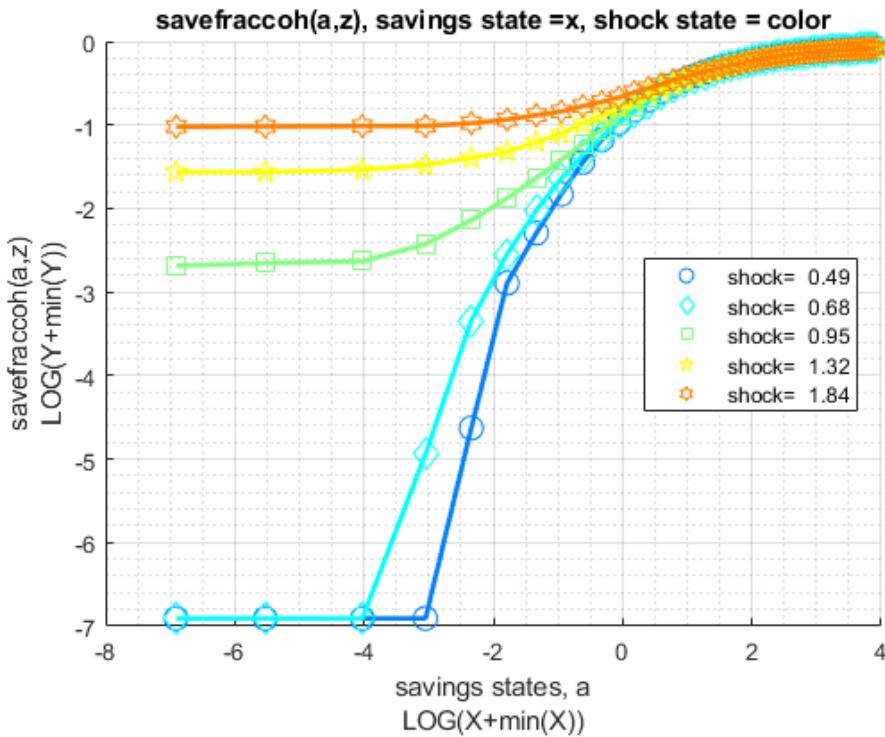
```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
% ls_ffcmd: summary print which outcomes
mp_support('ls_ffcmd') = {};
% ls_ffsna: detail print which outcomes
mp_support('ls_ffsna') = {'savefraccoh'};
% ls_ffgrh: graphical print which outcomes
mp_support('ls_ffgrh') = {'savefraccoh'};
ff_vfi_az_bisec_vec(mp_params, mp_support);
```

Elapsed time is 0.494900 seconds.

xxx ff_vfi_az_vec, outcome=savefraccoh		xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx	mean_z_0_4858	mean_z_0_67798	mean_z_0_9462	mean_z_1_3205	mean_z_
group	a	-----	-----	-----	-----	-----	-----
1	0	-----	0	0	0.067239	0.20859	0.3
2	0.002975	-----	0	0	0.069375	0.20829	0.3
3	0.016829	-----	0	0	0.070901	0.2139	0.3
4	0.046375	-----	0	0.0061439	0.087319	0.2266	0.3
5	0.095198	0.0087684	-----	0.034403	0.1168	0.2468	0.3
6	0.1663	0.054361	-----	0.077248	0.1522	0.26639	0.3
7	0.26234	0.099892	-----	0.13132	0.19388	0.29929	0.4
8	0.38568	0.15958	-----	0.19309	0.24112	0.33017	0.4
9	0.53852	0.23417	-----	0.25553	0.29215	0.37436	0.4
10	0.72291	0.3071	-----	0.31656	0.34812	0.41153	0.4
11	0.94076	0.37595	-----	0.37503	0.40842	0.44925	0.5
12	1.1939	0.43881	-----	0.42941	0.45755	0.48697	0.5
13	1.484	0.49509	-----	0.48129	0.50381	0.53262	0.5
14	1.8128	0.54489	-----	0.53018	0.54642	0.56778	0.5
15	2.1817	0.58871	-----	0.57382	0.58548	0.60055	0.
16	2.5924	0.62716	-----	0.61258	0.62076	0.63101	0.6
17	3.0463	0.66079	-----	0.64682	0.65243	0.65884	0.
18	3.5449	0.69027	-----	0.67709	0.68069	0.68423	0.6
19	4.0894	0.71621	-----	0.70376	0.70596	0.70724	0.7
20	4.6813	0.73703	-----	0.72732	0.72848	0.72799	0.7
21	5.3218	0.75326	-----	0.74813	0.7485	0.74673	0.7
22	6.0121	0.76913	-----	0.76657	0.76632	0.76364	0.7
23	6.7536	0.78536	-----	0.78286	0.78231	0.77889	0.
24	7.5474	0.79983	-----	0.79745	0.79653	0.79269	0.

25	8.3948	0.81271	0.81039	0.80929	0.80514	0.8
26	9.2967	0.82418	0.82198	0.82076	0.81637	0.8
27	10.254	0.8345	0.83242	0.83114	0.82656	0.8
28	11.269	0.84377	0.84176	0.84042	0.83584	0.8
29	12.342	0.85214	0.85024	0.84884	0.8442	0.8
30	13.473	0.85964	0.85781	0.85647	0.85183	0.8
31	14.665	0.86648	0.86471	0.86337	0.85879	0.8
32	15.918	0.87264	0.87099	0.86965	0.86507	0.8
33	17.233	0.87826	0.87667	0.87533	0.87161	0.8
34	18.611	0.88338	0.88186	0.88052	0.87771	0.8
35	20.053	0.88802	0.88656	0.88528	0.88326	0.8
36	21.56	0.8923	0.89089	0.88967	0.88833	0.8
37	23.133	0.89614	0.89486	0.89364	0.8926	0.8
38	24.773	0.89974	0.89852	0.8973	0.89626	0.
39	26.481	0.90304	0.90182	0.90072	0.89968	0.8
40	28.258	0.90603	0.90493	0.90383	0.90279	0.8
41	30.104	0.90884	0.90774	0.9067	0.90572	0.9
42	32.021	0.9114	0.91036	0.90932	0.90841	0.9
43	34.01	0.91378	0.9128	0.91183	0.91091	0.9
44	36.07	0.91598	0.91506	0.91408	0.91317	0.9
45	38.204	0.91805	0.91714	0.91622	0.91537	0.9
46	40.412	0.91994	0.91909	0.91817	0.91732	0.9
47	42.695	0.92171	0.92086	0.92001	0.91921	0.
48	45.053	0.92336	0.92257	0.92171	0.92092	0.9
49	47.488	0.92489	0.92409	0.92336	0.92257	0.9
50	50	0.92629	0.92562	0.92489	0.92428	0.9





Run the function and show summaries for savings and fraction of coh saved:

```
mp_params('it_a_n') = 100;
mp_params('it_z_n') = 9;
mp_support('ls_ffcmd') = {'ap', 'savefraccoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {};
mp_support('bl_vfi_store_all') = true; % store c(a,z), y(a,z)
ff_vfi_az_bisec_vec(mp_params, mp_support);
```

Elapsed time is 1.164186 seconds.

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coef
	-	---	----	-----	----	----	-----	-----	-----	-----
ap	1	1	2	900	100	9	12926	14.362	14.544	1.0
savefraccoh	2	2	2	900	100	9	621.24	0.69027	0.26896	0.38

xxx TABLE:ap xxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6	c7	c8
	-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0.087442	0.27778	0.58243	1.0038
r2	0	0	0	0	0.087962	0.27828	0.58297	1.0044
r3	0	0	0	0	0.090477	0.28074	0.58547	1.0069
r4	0	0	0	0.00055771	0.09279	0.28605	0.5907	1.0122
r5	0	0	0	0.0059496	0.09602	0.29477	0.59952	1.0209
r96	43.845	43.923	44.022	44.198	44.428	44.722	45.103	45.546
r97	45.031	45.101	45.208	45.384	45.613	45.91	46.293	46.735
r98	46.237	46.297	46.411	46.59	46.818	47.115	47.501	47.948
r99	47.46	47.512	47.635	47.812	48.041	48.34	48.726	49.191

r100	48.703	48.746	48.878	49.055	49.283	49.586	49.978	50.495
xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxxxxxxxxx								
	c1	c2	c3	c4	c5	c6	c7	c8
-----	-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0.066018	0.16569	0.27445	0.37369
r2	0	0	0	0	0.066384	0.16593	0.27463	0.37381
r3	0	0	0	0	0.068154	0.16715	0.27549	0.37442
r4	0	0	0	0.00052879	0.069619	0.16978	0.27726	0.37564
r5	0	0	0	0.0055946	0.071572	0.17405	0.28025	0.37766
r96	0.92458	0.92354	0.92226	0.92171	0.92116	0.92055	0.91994	0.91842
r97	0.92531	0.92416	0.92306	0.92251	0.92196	0.92141	0.92086	0.91933
r98	0.92605	0.9247	0.92379	0.9233	0.92275	0.9222	0.92171	0.92031
r99	0.92672	0.92525	0.92452	0.92403	0.92348	0.923	0.92251	0.92147
r100	0.92739	0.9258	0.92525	0.92477	0.92422	0.92379	0.92342	0.92336

1.4.4 Test FF_VFI_AZ_BISEC_VEC Change Interest Rate and Discount

Show only save fraction of cash on hand:

```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {'savefraccoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {};
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 100;
mp_params('it_z_n') = 7;
mp_params('fl_a_max') = 50;
mp_params('st_grid_type') = 'grid_powerspace';
```

Solve the model with several different interest rates and discount factor:

```
% Lower Savings Incentives
mp_params('fl_beta') = 0.80;
mp_params('fl_r') = 0.01;
ff_vfi_az_bisec_vec(mp_params, mp_support);
```

Elapsed time is 0.271658 seconds.

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coef
	-	---	----	----	----	----	----	-----	-----	-----
savefraccoh	1	1	2	700	100	7	357.85	0.51122	0.27528	0.53
xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxxxxxxxxx										
	c1	c2	c3	c4	c5	c6	c7			
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0	0	0.00022362	0.041544		
r2	0	0	0	0	0	0	0.00022362	0.041544		
r3	0	0	0	0	0	0	0.0011391	0.041544		
r4	0	0	0	0	0	0	0.0016884	0.041483		
r5	0	0	0	0	0	0	0.0034584	0.04136		
r96	0.79586	0.79275	0.78945	0.78591	0.78225	0.77853	0.77059			

```

r97    0.79684    0.79379    0.79055    0.78713    0.78359    0.77993    0.77212
r98    0.79782    0.79482    0.79171    0.78835    0.78488    0.78127    0.77365
r99    0.79873    0.79586    0.79275    0.78951    0.7861     0.78262    0.77548
r100   0.79965    0.79684    0.79385    0.79061    0.78732    0.7839     0.7781

% Higher Savings Incentives
mp_params('fl_beta') = 0.95;
mp_params('fl_r') = 0.04;
ff_vfi_az_bisec_vec(mp_params, mp_support);

Elapsed time is 0.971218 seconds.
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

      i   idx  ndim  numel  rowN  colN  sum  mean  std  coef
      -   ---  ----  -----  ----  ----  ----  -----  -----  -----
savefraccoh  1     1     2     700    100     7   481.37  0.68768  0.27118  0.39

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx
      c1      c2      c3      c4      c5      c6      c7
      -----  -----  -----  -----  -----  -----  -----
r1      0       0       0   0.065774  0.18076  0.30655  0.41654
r2      0       0       0   0.066201  0.18101  0.30674  0.4166
r3      0       0       0   0.06791   0.18223  0.30747  0.41709
r4      0       0       0   0.069619  0.18467  0.30759  0.41812
r5      0       0       0   0.071694  0.18876  0.30838  0.41983
r96    0.92428  0.92245  0.92178  0.92116  0.92049  0.91872  0.91824
r97    0.92501  0.92324  0.92257  0.92196  0.92129  0.91958  0.91921
r98    0.92574  0.92397  0.92336  0.92275  0.92208  0.92049  0.92025
r99    0.92647  0.9247   0.92409  0.92348  0.92287  0.92147  0.92159
r100   0.92702  0.92544  0.92483  0.92422  0.92373  0.92336  0.92348

```

1.4.5 Test FF_VFI_AZ_BISEC_VEC Changing Risk Aversion

Here, again, show fraction of coh saved in summary tabular form, but also show it graphically.

```

mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {'savefraccoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {'savefraccoh'};
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 100;
mp_params('it_z_n') = 7;
mp_params('fl_a_max') = 50;
mp_params('st_grid_type') = 'grid_powerspace';

```

Solve the model with different risk aversion levels, higher preferences for risk:

```

% Lower Risk Aversion
mp_params('fl_crra') = 0.5;
ff_vfi_az_bisec_vec(mp_params, mp_support);

```

Elapsed time is 0.873752 seconds.

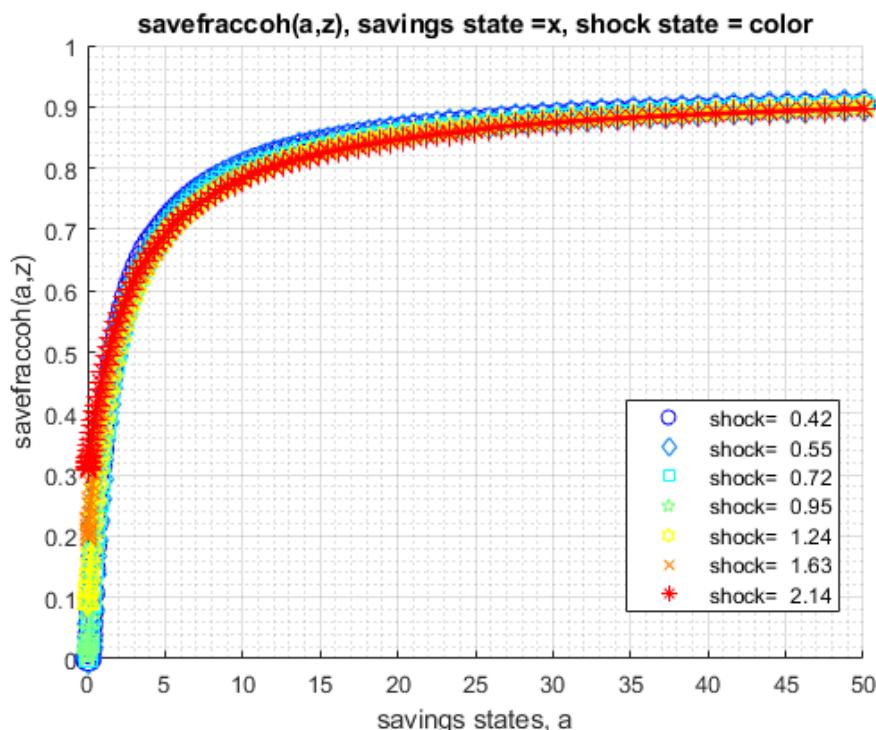
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

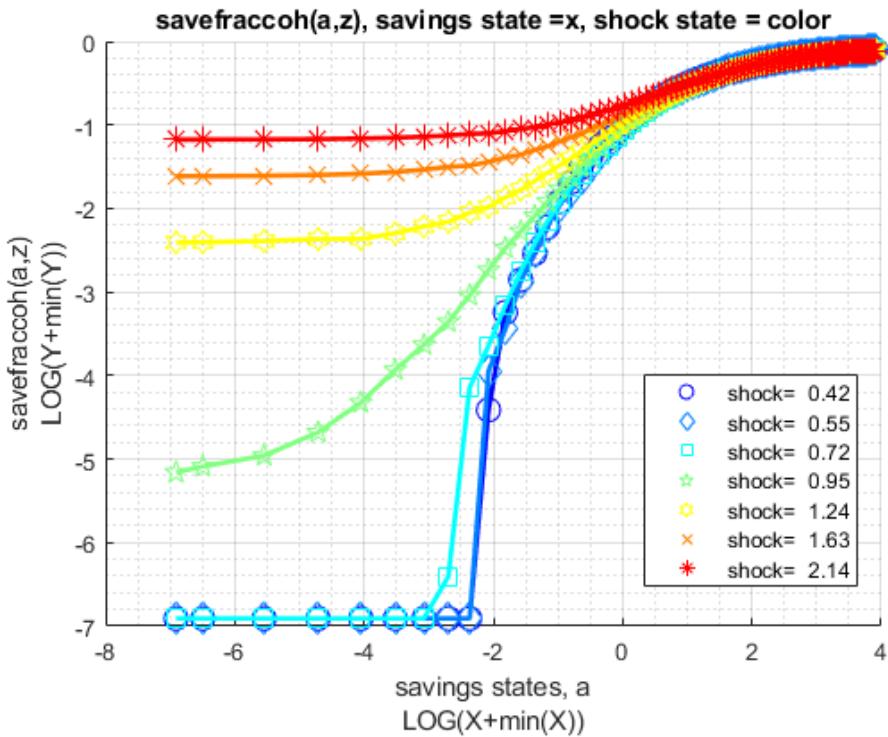
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefv
	-	---	----	-----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	700	100	7	452.13	0.6459	0.28031	0.433

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6	c7
	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0.0047401	0.089089	0.19822	0.30783
r2	0	0	0	0.0051674	0.089394	0.1984	0.30796
r3	0	0	0	0.0060218	0.090676	0.19926	0.30851
r4	0	0	0	0.0082801	0.092812	0.20115	0.30973
r5	0	0	0	0.012247	0.092995	0.2042	0.31174
r96	0.90047	0.89925	0.89828	0.8973	0.89632	0.89376	0.89297
r97	0.90127	0.90017	0.89919	0.89828	0.8973	0.8948	0.89394
r98	0.90206	0.90102	0.90011	0.89919	0.89828	0.89577	0.89498
r99	0.90279	0.90188	0.90102	0.90011	0.89919	0.89681	0.8959
r100	0.90359	0.90273	0.90188	0.90096	0.90011	0.89803	0.89687





When risk aversion increases, at every state-space point, the household wants to save more.

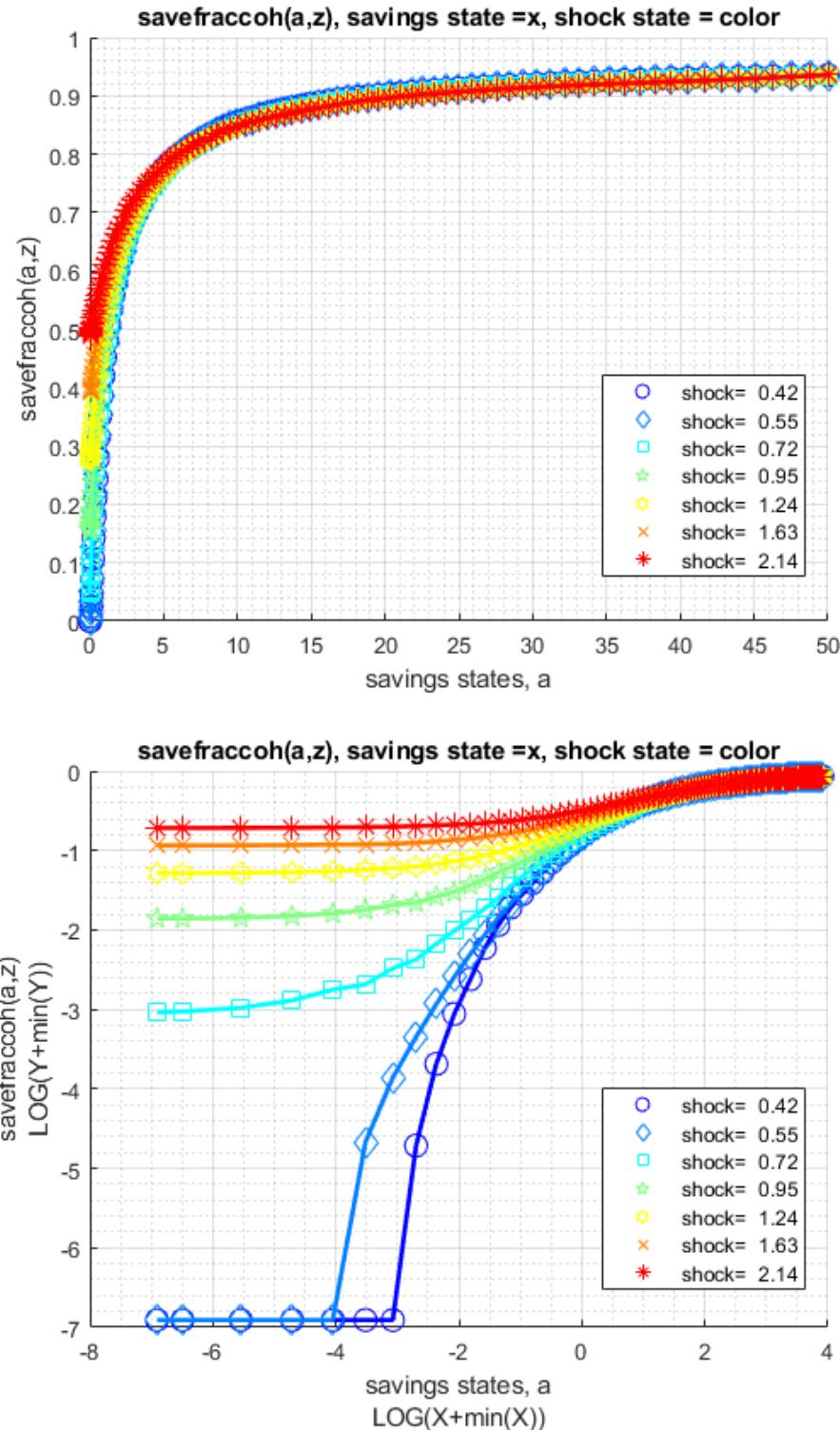
```
% Higher Risk Aversion
mp_params('fl_crra') = 5;
ff_vfi_az_bisec_vec(mp_params, mp_support);

Elapsed time is 0.970314 seconds.
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coef
	-	---	----	-----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	700	100	7	502.71	0.71816	0.25437	0.3

```
xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx
   c1      c2      c3      c4      c5      c6      c7
   -----  -----  -----  -----  -----  -----  -----
r1        0        0  0.047037  0.15537  0.27573  0.3909  0.48782
r2        0        0  0.047525  0.15531  0.27591  0.39102 0.48795
r3        0        0  0.049844  0.1569   0.27695  0.3917  0.48837
r4        0        0  0.054788  0.16025  0.27915  0.3931  0.48929
r5        0        0  0.062905  0.16569  0.28275  0.39542 0.49075
r96  0.93307  0.93258  0.93203  0.93154  0.9302  0.92995 0.92971
r97  0.93374  0.93325  0.93276  0.93227  0.93111 0.93105 0.93117
r98  0.93441  0.93398  0.93349  0.93307  0.93209 0.93227 0.9327
r99  0.93508  0.93465  0.93423  0.93392  0.93331 0.93368 0.93435
r100 0.93575  0.93539  0.93508  0.9349   0.93496 0.93526 0.93587
```



1.4.6 Test FF_VFI_AZ_BISEC_VEC with Higher Uncertainty

Increase the standard deviation of the Shock.

```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {'savefraccoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {};
```

```

mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 150;
mp_params('it_z_n') = 15;
mp_params('fl_a_max') = 50;
mp_params('st_grid_type') = 'grid_powerspace';
% graph color spectrum
mp_params('cl_colors') = 'copper';

```

Lower standard deviation of shock:

```
% Lower Risk Aversion
mp_params('fl_shk_std') = 0.10;
ff_vfi_az_bisec_vec(mp_params, mp_support);
```

Elapsed time is 2.595920 seconds.

xx
CONTAINER NAME: mp_ffcmd ND Array (Matrix e
xx

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coef
	-	---	----	-----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	2250	150	15	1507.5	0.67001	0.28668	0.42
xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxxxxx										
	c1	c2	c3	c4	c5	c11	c12	c13		
	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0	0.13847	0.18485	0.23026		
r2	0	0	0	0	0	0.13853	0.18491	0.23032		
r3	0	0	0	0	0	0.13895	0.18528	0.23063		
r4	0	0	0	0	0	0.13987	0.18607	0.2313		
r5	0	0	0	0	0	0.14011	0.18735	0.2324		
r146	0.92373	0.92354	0.9233	0.92312	0.92287	0.92086	0.92068	0.92049		
r147	0.92422	0.92403	0.92385	0.92361	0.92342	0.92141	0.92123	0.92098		
r148	0.9247	0.92452	0.92434	0.92409	0.92391	0.9219	0.92171	0.92153		
r149	0.92519	0.92501	0.92483	0.92458	0.9244	0.92245	0.92226	0.92208		
r150	0.92568	0.9255	0.92531	0.92507	0.92489	0.92293	0.92275	0.92257		

Higher shock standard deviation: low shock high asset save more, high shock more asset save less, high shock low asset save more;

```
% Higher Risk Aversion
mp_params('fl_shk_std') = 0.40;
ff vfi az biseq vec(mp_params, mp_support);
```

Elapsed time is 2.805227 seconds.

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx  
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)  
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

r1	0	0	0	0	0	0.5264	0.61264	0.68271
r2	0	0	0	0	0	0.52646	0.61264	0.68271
r3	0	0	0	0	0	0.52658	0.6127	0.68271
r4	0	0	0	0	0	0.52682	0.61288	0.68283
r5	0	0	0	0	0	0.52731	0.61313	0.68295
r146	0.92983	0.92928	0.92873	0.92806	0.92739	0.92269	0.92354	0.9258
r147	0.9302	0.92971	0.9291	0.92849	0.92788	0.92361	0.92477	0.9269
r148	0.93056	0.93008	0.92953	0.92892	0.92831	0.92458	0.92593	0.928
r149	0.93093	0.93044	0.92995	0.92934	0.92873	0.9258	0.92702	0.9291
r150	0.9313	0.93087	0.93032	0.92977	0.92916	0.92696	0.92818	0.93014

1.5 FF_VFI_AZ_MZOOM_LOOP Savings Loop Exact (VALUE) Examples

Go back to fan's MEconTools Toolbox (bookdown), Matlab Code Examples Repository (bookdown), or Math for Econ with Matlab Repository (bookdown).

This is the example vignette for function: **ff_vfi_az_mzoom_loop** from the **MEconTools Package**. This function solves the dynamic programming problem for a (a,z) model. The state-space is on a grid, but choice grids are in terms of **percentage of resources** to save and solved exactly.

This is a **looped** code for **continuous** choices, solved with the **mzoom** algorithm. In contrast to the **bisection** based solution, this is slower, but this does not rely on first order conditions.

Links to Other Code:

Core Savings/Borrowing Dynamic Programming Solution Functions that are functions in the [MEcon-Tools Package](#). :

- Common Choice and States Grid : `ff_vfi_az_loop`
 - Common Choice and States Grid : `ff_vfi_az_vec`
 - States Grid + Continuous Exact Savings as Share of Cash-on-Hand, rely on FOC, :`ff_vfi_az_bisec_loop`
 - States Grid + Continuous Exact Savings as Share of Cash-on-Hand, rely on FOC :
`ff_vfi_az_bisec_vec`
 - States Grid + Continuous Exact Savings as Share of Cash-on-Hand, VALUE comparison,
`ff_vfi_az_mzoom_loop`
 - States Grid + Continuous Exact Savings as Share of Cash-on-Hand, VALUE comparison, :
`ff_vfi_az_mzoom_vec`

1.5.1 Test FF VFI AZ MZOOM LOOP Defaults

Call the function with defaults. By default, shows the asset policy function summary. Model parameters can be changed by the mp_params.

```
%mp_params
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('fl_crra') = 1.5;
mp_params('fl_beta') = 0.94;
% call function
ff_vfi_az_mzoom_loop(mp_params);
```

Elapsed time is 83.956071 seconds.

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx  
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)  
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

i	idx	ndim	numel	rowN	colN	sum	mean	std	coefvari	min
-	---	----	----	----	----	----	----	----	-----	----

ap	1	1	2	700	100	7	9861.5	14.088	14.386	1.0212	0
xxx TABLE:ap xxxxxxxxxxxxxxxxxxxxxxx											
	c1	c2	c3	c4	c5	c6	c7				
	-----	-----	-----	-----	-----	-----	-----				
r1	0	0	0	0.05343	0.25568	0.60598	1.1155				
r2	0	0	0	0.053451	0.25571	0.60652	1.1161				
r3	0	0	0	0.056468	0.25574	0.60897	1.1174				
r4	0	0	0	0.061232	0.25995	0.61042	1.1238				
r5	0	0	0	0.065929	0.2689	0.61091	1.1323				
r96	43.387	43.517	43.7	43.922	44.221	44.657	45.225				
r97	44.562	44.694	44.876	45.095	45.392	45.847	46.394				
r98	45.758	45.89	46.071	46.287	46.583	47.037	47.596				
r99	46.972	47.103	47.285	47.5	47.794	48.247	48.812				
r100	48.183	48.337	48.518	48.732	49.025	49.478	50.115				

1.5.2 Test FF_VFI_AZ_MZOOM_LOOP Speed Tests

Call the function with defaults. By default, shows the asset policy function summary. Model parameters can be changed by the mp_params.

```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_timer') = true;
mp_support('ls_ffcmd') = {};
```

A grid 50, shock grid 5:

```
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 50;
mp_params('it_z_n') = 5;
ff_vfi_az_mzoom_loop(mp_params, mp_support);
```

Elapsed time is 26.554641 seconds.

A grid 750, shock grid 15:

```
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 750;
mp_params('it_z_n') = 15;
ff_vfi_az_mzoom_loop(mp_params, mp_support);
```

Elapsed time is 2148.508425 seconds.

A grid 600, shock grid 45:

```
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 600;
mp_params('it_z_n') = 45;
ff_vfi_az_mzoom_loop(mp_params, mp_support);
```

Elapsed time is 8507.097739 seconds.

1.5.3 Test FF_VFI_AZ_MZOOM_LOOP Control Outputs

Run the function first without any outputs, but only the timer.

```
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 50;
mp_params('it_z_n') = 5;
mp_support = containers.Map('KeyType','char', 'ValueType','any');
```

```

mp_support('bl_timer') = true;
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {};
ff_vfi_az_mzoom_loop(mp_params, mp_support);

```

Elapsed time is 24.011245 seconds.

Run the function and show policy function for savings choice. For ls_ffcmd, ls_ffsna, ls_ffgrh, can include these: 'v', 'ap', 'c', 'y', 'coh', 'savefraccoh'. These are value, ap prime savings choice, consumption, income, cash on hand, and savings fraction as cash-on-hand.

```

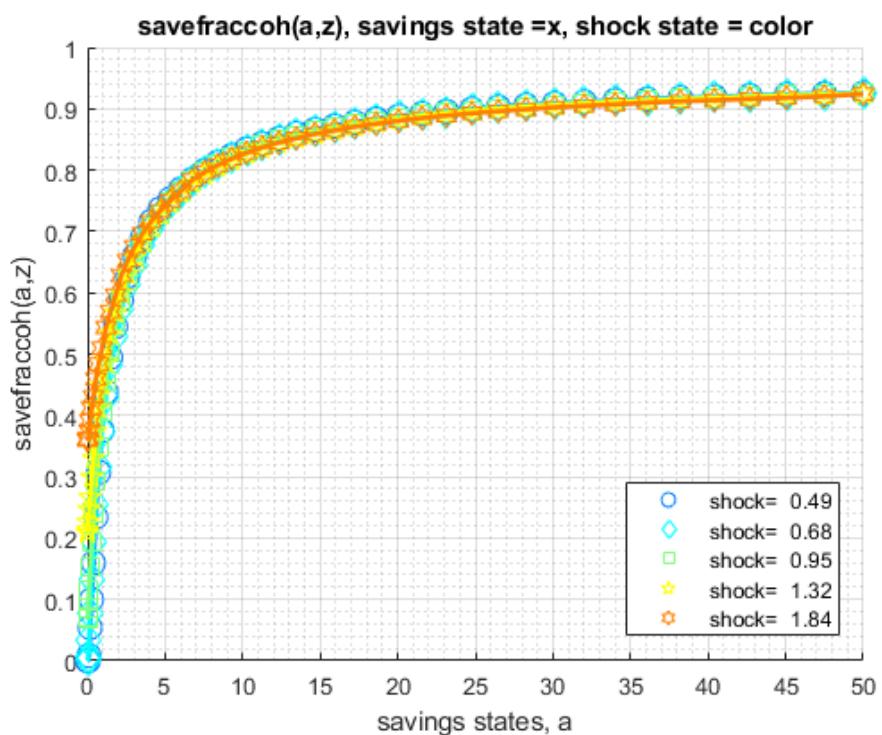
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
% ls_ffcmd: summary print which outcomes
mp_support('ls_ffcmd') = {};
% ls_ffsna: detail print which outcomes
mp_support('ls_ffsna') = {'savefraccoh'};
% ls_ffgrh: graphical print which outcomes
mp_support('ls_ffgrh') = {'savefraccoh'};
ff_vfi_az_mzoom_loop(mp_params, mp_support);

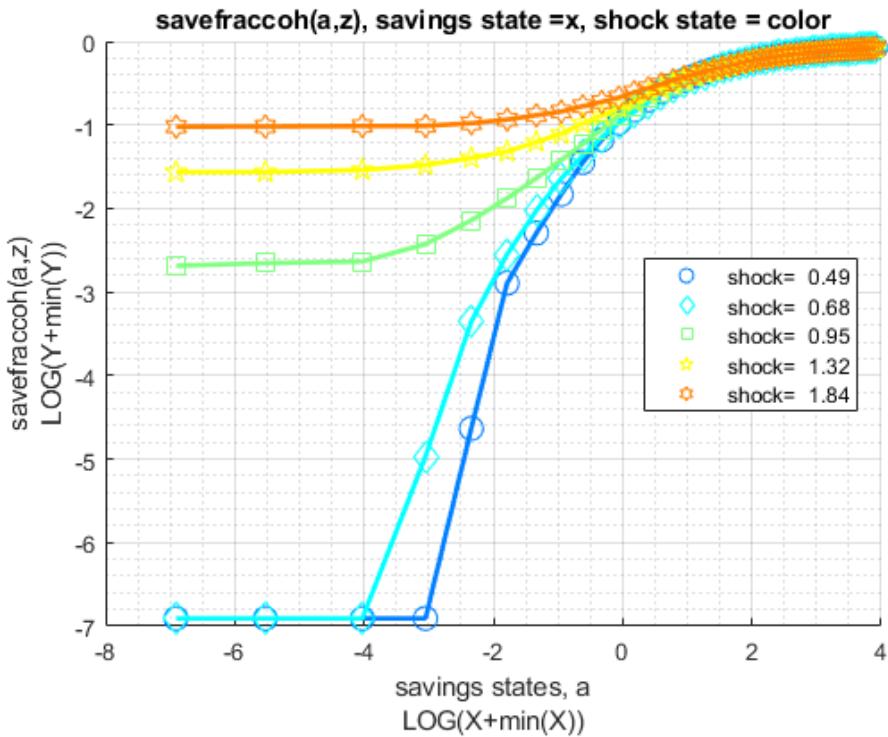
```

Elapsed time is 23.773078 seconds.

group	a	mean_z_0_4858	mean_z_0_67798	mean_z_0_9462	mean_z_1_3205	mean_z_
1	0	0	0	0.067148	0.2084	0.3
2	0.002975	0	0	0.069345	0.20826	0.3
3	0.016829	0	0	0.070749	0.2136	0.3
4	0.046375	0	0.0059631	0.08732	0.22641	0.3
5	0.095198	0.008725	0.033935	0.11637	0.24674	0.
6	0.1663	0.054327	0.077152	0.15198	0.26635	0.3
7	0.26234	0.099882	0.13131	0.1936	0.29922	0.4
8	0.38568	0.15954	0.1928	0.24107	0.33005	0.4
9	0.53852	0.23411	0.25482	0.29164	0.37407	0.
10	0.72291	0.30704	0.31604	0.34806	0.41148	0.4
11	0.94076	0.37567	0.37487	0.40768	0.44925	0.5
12	1.1939	0.43849	0.42939	0.4573	0.48691	0.5
13	1.484	0.49491	0.48129	0.50332	0.53253	0.5
14	1.8128	0.54486	0.53013	0.54642	0.56773	0.5
15	2.1817	0.58868	0.57335	0.58545	0.60016	0.6
16	2.5924	0.6271	0.61254	0.62056	0.63057	0.6
17	3.0463	0.66058	0.6468	0.65237	0.65884	0.6
18	3.5449	0.69019	0.67699	0.68069	0.68379	0.6
19	4.0894	0.71615	0.70375	0.7058	0.70719	0.
20	4.6813	0.73661	0.72701	0.72843	0.72781	0.7
21	5.3218	0.75302	0.7481	0.74821	0.74661	0.7
22	6.0121	0.76912	0.76622	0.76622	0.76342	0.7
23	6.7536	0.78503	0.78285	0.78223	0.77885	0.7
24	7.5474	0.79943	0.79703	0.79623	0.79223	0.7
25	8.3948	0.81264	0.81024	0.8093	0.80504	0.8
26	9.2967	0.82384	0.82198	0.82064	0.81634	0.8
27	10.254	0.83447	0.83225	0.83065	0.82653	0.8
28	11.269	0.84345	0.84174	0.84025	0.83545	0.8
29	12.342	0.85185	0.85017	0.84865	0.84417	0.8
30	13.473	0.85962	0.85746	0.85642	0.85178	0.8
31	14.665	0.86626	0.86466	0.86306	0.85873	0.8

32	15.918	0.87226	0.87066	0.86959	0.86504	0.8
33	17.233	0.87786	0.87626	0.87529	0.87146	0.8
34	18.611	0.88332	0.88182	0.88026	0.87766	0.8
35	20.053	0.888	0.88656	0.88507	0.88267	0.8
36	21.56	0.89187	0.89087	0.88947	0.88825	0.8
37	23.133	0.89587	0.89484	0.89347	0.89256	0.8
38	24.773	0.8997	0.89827	0.89727	0.89587	0.8
39	26.481	0.903	0.90147	0.90066	0.89964	0.8
40	28.258	0.90601	0.90467	0.90376	0.90278	0.8
41	30.104	0.90881	0.9077	0.90628	0.90547	0.9
42	32.021	0.91137	0.91035	0.90908	0.90838	0.9
43	34.01	0.91377	0.91275	0.91148	0.91068	0.9
44	36.07	0.91595	0.91468	0.91388	0.91308	0.9
45	38.204	0.91788	0.91708	0.91617	0.91531	0.9
46	40.412	0.91948	0.91868	0.91788	0.91708	0.9
47	42.695	0.92168	0.92085	0.91998	0.91915	0.9
48	45.053	0.92331	0.92251	0.92171	0.92091	0.9
49	47.488	0.92485	0.92408	0.92331	0.92254	0.
50	50	0.92588	0.92555	0.92485	0.92423	0.9





Run the function and show summaries for savings and fraction of coh saved:

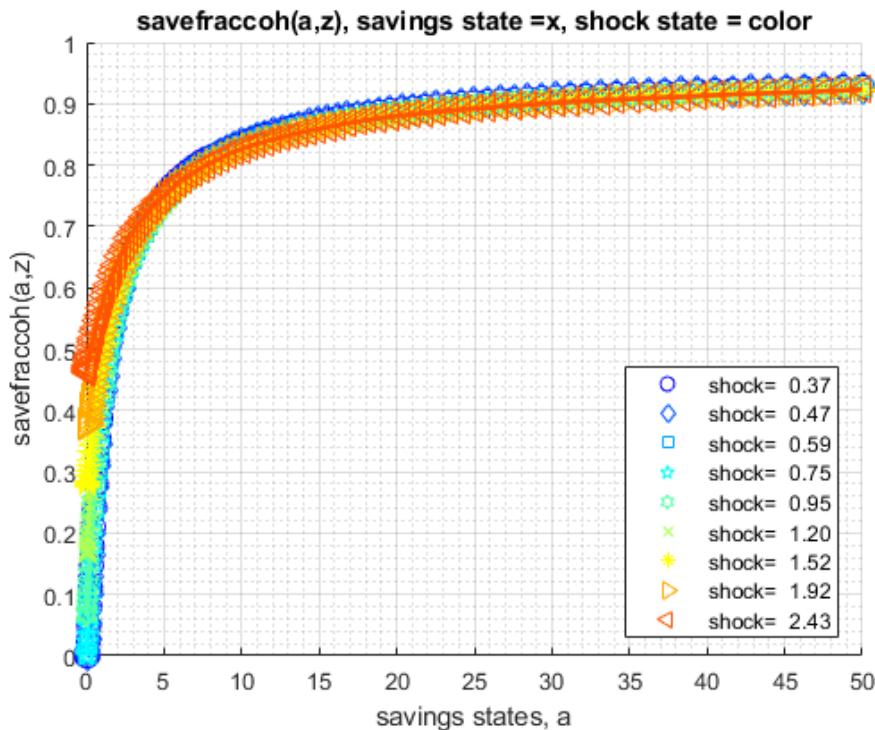
```
%mp_params
mp_params = containers.Map('KeyType','char', 'ValueType','any');
% mp_params('fl_crra') = 1.5;
% mp_params('fl_beta') = 0.94;
mp_params('it_a_n') = 100;
mp_params('it_z_n') = 9;
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
% ls_ffcmd: summary print which outcomes
mp_support('ls_ffcmd') = {};
% ls_ffsna: detail print which outcomes
mp_support('ls_ffsna') = {'savefraccoh'};
% ls_ffgrh: graphical print which outcomes
mp_support('ls_ffgrh') = {'savefraccoh'};
% call function
ff_vfi_az_mzoom_loop(mp_params, mp_support);
```

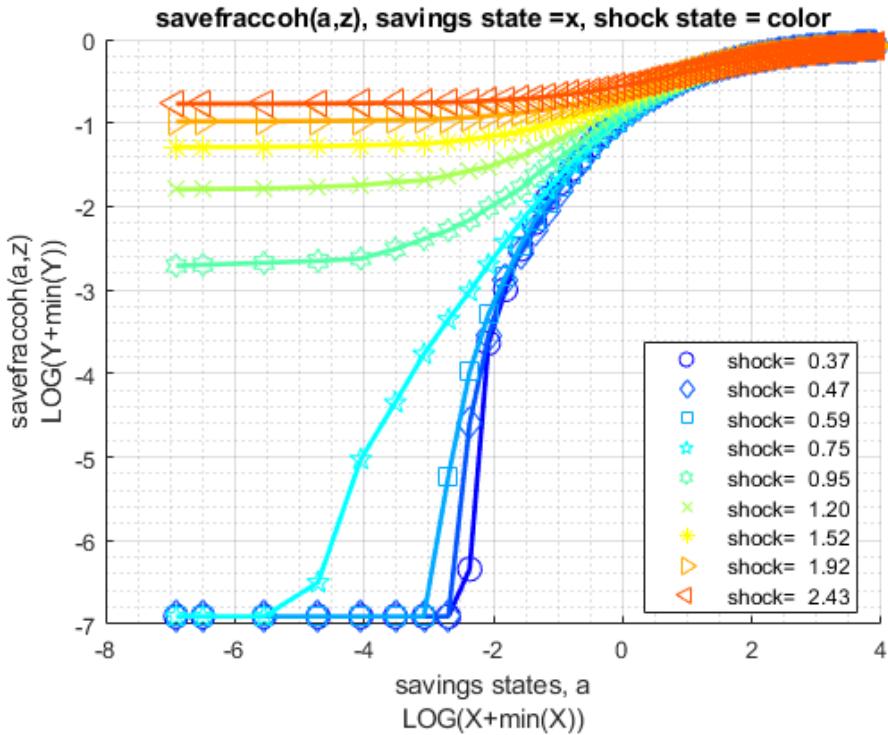
Elapsed time is 111.419370 seconds.

group	a	mean_z_0_36853	mean_z_0_46648	mean_z_0_59047	mean_z_0_74742	m
1	0	0	0	0	0	
2	0.00051272	0	0	0	0	
3	0.0029004	0	0	0	0	
4	0.0079925	0	0	0	0.00050216	
5	0.016407	0	0	0	0.005563	
6	0.028662	0	0	0	0.011926	
7	0.045213	0	0	0	0.022095	
8	0.06647	0	0	0.0043625	0.033935	
9	0.092813	0.00076108	0.0091251	0.017748	0.047979	

10	0.12459	0.02539	0.027791	0.036336	0.066347
11	0.16214	0.049062	0.054743	0.057497	0.087289
12	0.20576	0.080353	0.076351	0.084213	0.11115
13	0.25576	0.11036	0.10076	0.11357	0.13677
14	0.31242	0.14798	0.12866	0.14076	0.16483
15	0.37601	0.17839	0.16439	0.16895	0.194
16	0.4468	0.2098	0.20032	0.1988	0.22401
17	0.52503	0.24246	0.23721	0.23371	0.25482
18	0.61095	0.28123	0.27422	0.26803	0.28577
19	0.7048	0.31861	0.30964	0.30224	0.31644
20	0.8068	0.35352	0.34406	0.33561	0.34646
21	0.91719	0.38727	0.37774	0.36766	0.37639
22	1.0362	0.42001	0.40688	0.39888	0.40495
23	1.164	0.4501	0.43289	0.42881	0.43266
24	1.3008	0.47851	0.45746	0.45719	0.45922
25	1.4468	0.50572	0.48514	0.48371	0.48451
26	1.6023	0.53093	0.51118	0.50952	0.50892
27	1.7673	0.55214	0.53571	0.53333	0.53173
28	1.9422	0.57052	0.55854	0.55614	0.55374
29	2.127	0.58782	0.58031	0.57735	0.57415
30	2.3221	0.60768	0.60016	0.59758	0.59375
31	2.5275	0.62577	0.61947	0.61496	0.61226
32	2.7434	0.64351	0.63697	0.63101	0.62956
33	2.97	0.65976	0.65338	0.64537	0.64591
34	3.2075	0.67458	0.66898	0.66058	0.66124
35	3.456	0.68919	0.68379	0.67538	0.67538
36	3.7158	0.7022	0.69739	0.68939	0.68928
37	3.9869	0.7146	0.7098	0.7022	0.70205
38	4.2696	0.72668	0.7218	0.7146	0.7138
39	4.564	0.73741	0.73341	0.7262	0.7254
40	4.8702	0.74798	0.74381	0.73711	0.73581
41	5.1884	0.75768	0.75382	0.74727	0.74581
42	5.5188	0.76679	0.7618	0.75684	0.75542
43	5.8615	0.77502	0.76862	0.76542	0.76422
44	6.2166	0.78303	0.77658	0.77422	0.77262
45	6.5844	0.79063	0.78452	0.78223	0.78063
46	6.9649	0.79783	0.79196	0.78983	0.78823
47	7.3583	0.80499	0.79863	0.79695	0.79543
48	7.7647	0.81024	0.80566	0.80343	0.80231
49	8.1844	0.81504	0.81184	0.81003	0.80862
50	8.6173	0.81984	0.81744	0.81584	0.81424
51	9.0637	0.82544	0.82351	0.82144	0.82031
52	9.5237	0.83065	0.82881	0.82664	0.82544
53	9.9975	0.83545	0.83385	0.83217	0.83065
54	10.485	0.84025	0.83863	0.83697	0.83545
55	10.987	0.84494	0.84315	0.84155	0.84023
56	11.502	0.84919	0.84705	0.84585	0.84425
57	12.032	0.85319	0.85156	0.85002	0.84785
58	12.577	0.85666	0.85506	0.85396	0.85174
59	13.136	0.86064	0.85906	0.85746	0.85506
60	13.709	0.86386	0.86226	0.86122	0.85826
61	14.298	0.86706	0.86596	0.86461	0.86138
62	14.901	0.87052	0.86906	0.86746	0.86464
63	15.519	0.87306	0.87215	0.87066	0.86746
64	16.152	0.87626	0.87466	0.87378	0.87066
65	16.801	0.87866	0.87779	0.87626	0.8736
66	17.465	0.88163	0.88026	0.87923	0.87626
67	18.144	0.88409	0.88267	0.88179	0.87866

68	18.839	0.88646	0.88507	0.88422	0.88107
69	19.55	0.88867	0.88747	0.88653	0.88347
70	20.277	0.89087	0.88947	0.88867	0.88587
71	21.02	0.89267	0.89187	0.89087	0.88787
72	21.778	0.89493	0.89347	0.89267	0.89027
73	22.553	0.89667	0.89582	0.89487	0.89187
74	23.345	0.89827	0.89747	0.89667	0.89422
75	24.152	0.90034	0.89907	0.89827	0.89587
76	24.977	0.90204	0.90111	0.89987	0.89747
77	25.818	0.90361	0.90274	0.90147	0.89907
78	26.675	0.90515	0.90387	0.90307	0.90067
79	27.55	0.90628	0.90547	0.90467	0.90227
80	28.441	0.90788	0.90708	0.90547	0.90387
81	29.35	0.90908	0.9086	0.90708	0.90547
82	30.276	0.91068	0.90988	0.90825	0.90697
83	31.219	0.91195	0.91121	0.90908	0.90828
84	32.179	0.91308	0.91228	0.91035	0.90958
85	33.157	0.91388	0.91361	0.91148	0.91068
86	34.153	0.91543	0.91468	0.91228	0.91198
87	35.166	0.91628	0.91548	0.9138	0.91308
88	36.198	0.91708	0.91688	0.91468	0.91388
89	37.247	0.91851	0.91786	0.91548	0.91527
90	38.314	0.91946	0.91868	0.91691	0.91628
91	39.399	0.92028	0.91948	0.91788	0.91708
92	40.503	0.92108	0.92028	0.91868	0.91788
93	41.625	0.92188	0.92108	0.91948	0.91868
94	42.765	0.92268	0.92188	0.92028	0.92001
95	43.924	0.92348	0.92268	0.92108	0.92085
96	45.102	0.92428	0.92348	0.92188	0.92168
97	46.298	0.92508	0.92414	0.92268	0.92248
98	47.513	0.92588	0.92469	0.92348	0.92325
99	48.747	0.92668	0.92508	0.92428	0.92398
100	50	0.92737	0.9258	0.92508	0.92428





1.5.4 Test FF_VFI_AZ_MZOOM_LOOP Change Interest Rate and Discount

Show only save fraction of cash on hand:

```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {'savefraccoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {};
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 750;
mp_params('it_z_n') = 9;
mp_params('fl_a_max') = 50;
mp_params('st_grid_type') = 'grid_powerspace';
```

Solve the model with several different interest rates and discount factor:

```
% Lower Savings Incentives
mp_params('fl_beta') = 0.80;
mp_params('fl_r') = 0.01;
ff vfi_az mzoom_loop(mp_params, mp_support);
```

Elapsed time is 294.329574 seconds.

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx  
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)  
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefv
	-	---	----	-----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	6750	750	9	3468.2	0.5138	0.27192	0.529

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6	c7	c8
	-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0	0	0	0.02073
r2	0	0	0	0	0	0	0	0.02073
r3	0	0	0	0	0	0	0	0.02073
r4	0	0	0	0	0	0	0	0.02073
r5	0	0	0	0	0	0	0	0.02073
r746	0.8008	0.79843	0.7959	0.79303	0.78983	0.78663	0.78303	0.77903
r747	0.80092	0.79855	0.79603	0.79303	0.79058	0.78713	0.78362	0.77953
r748	0.80102	0.79863	0.79615	0.7935	0.79063	0.78729	0.78378	0.77972
r749	0.80103	0.79863	0.79623	0.79369	0.79063	0.78743	0.78383	0.77983
r750	0.80103	0.79904	0.79623	0.79378	0.79063	0.78743	0.78383	0.77983


```
% Higher Savings Incentives
mp_params('fl_beta') = 0.95;
mp_params('fl_r') = 0.04;
ff_vfi_az_mzoom_loop(mp_params, mp_support);
```

Elapsed time is 1309.412430 seconds.

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	cofv
	-	---	----	----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	6750	750	9	4667.7	0.6915	0.26685	0.38


```
xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx
```

	c1	c2	c3	c4	c5	c6	c7	c8
	-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0.0647	0.16668	0.27352	0.37327
r2	0	0	0	0	0.0647	0.16668	0.27352	0.37327
r3	0	0	0	0	0.064731	0.16668	0.27352	0.37327
r4	0	0	0	0	0.064731	0.16668	0.27355	0.37327
r5	0	0	0	0	0.064747	0.16671	0.27355	0.37327
r746	0.92657	0.92588	0.92508	0.92428	0.92348	0.92268	0.92235	0.92188
r747	0.92664	0.92588	0.92508	0.92428	0.92402	0.92318	0.92248	0.92188
r748	0.92668	0.92588	0.92508	0.92478	0.92411	0.92328	0.9226	0.92188
r749	0.92668	0.92588	0.92555	0.92488	0.9242	0.9234	0.92268	0.92254
r750	0.92668	0.92588	0.92565	0.92497	0.92427	0.92348	0.92268	0.92268

1.5.5 Test FF_VFI_AZ_MZOOM_LOOP Changing Risk Aversion

Here, again, show fraction of coh saved in summary tabular form, but also show it graphically.

```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {'savefraccoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {'savefraccoh'};
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 100;
mp_params('it_z_n') = 7;
mp_params('fl_a_max') = 50;
mp_params('st_grid_type') = 'grid_powerspace';
```

Solve the model with different risk aversion levels, higher preferences for risk:

```
% Lower Risk Aversion
mp_params('fl_crra') = 0.5;
ff_vfi_az_mzoom_loop(mp_params, mp_support);
```

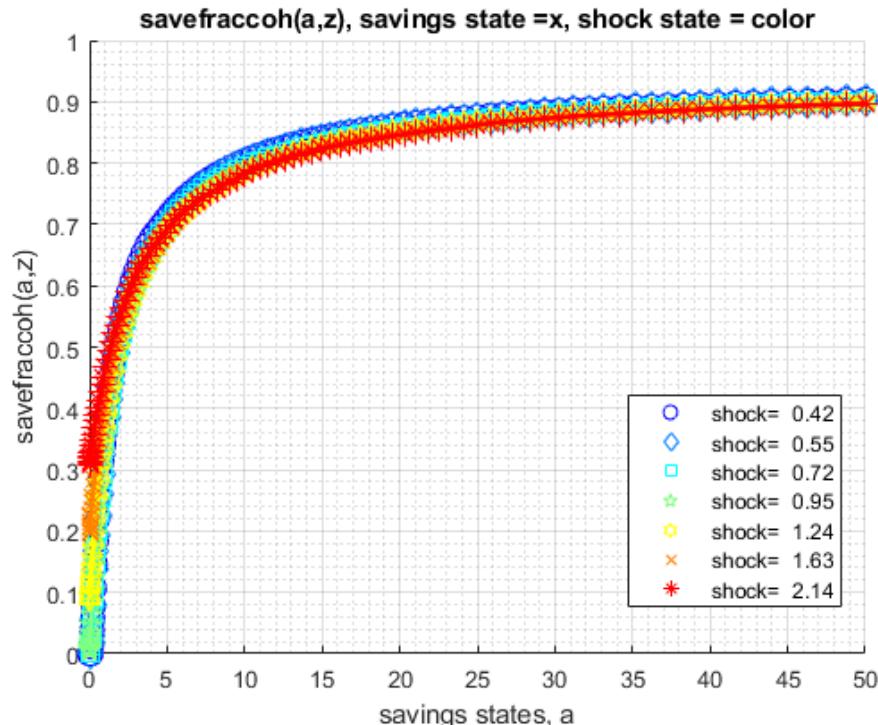
Elapsed time is 84.461743 seconds.

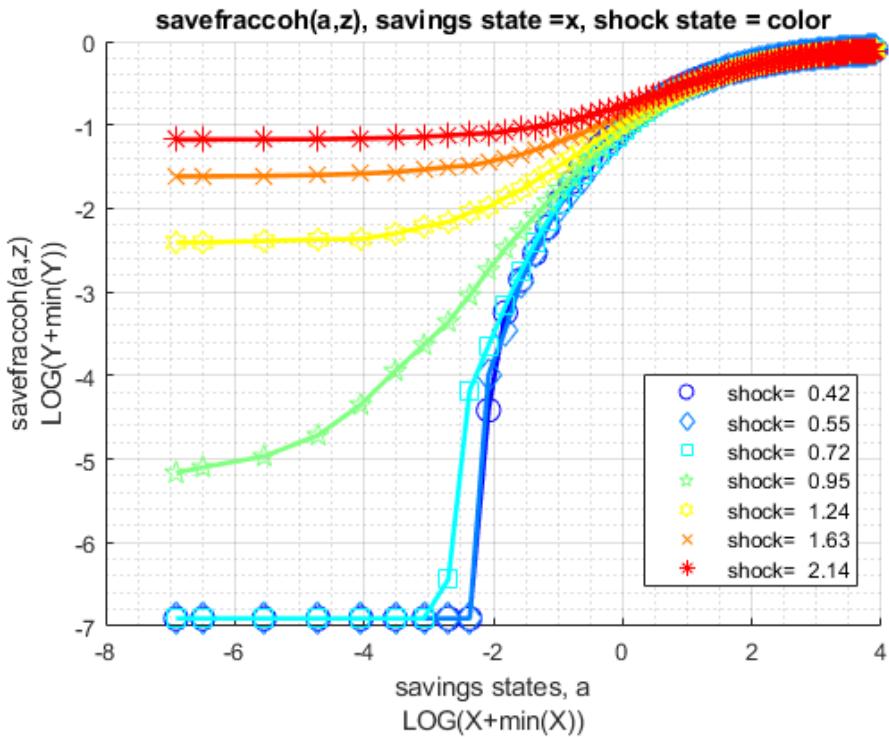
```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coef
	-	---	----	-----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	700	100	7	452.03	0.64575	0.28029	0.43

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6	c7
	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0.0047077	0.089109	0.198	0.30781
r2	0	0	0	0.0051079	0.089156	0.198	0.30793
r3	0	0	0	0.0059631	0.090679	0.1988	0.30848
r4	0	0	0	0.0079639	0.092358	0.20109	0.30964
r5	0	0	0	0.011926	0.092758	0.20413	0.31171
r96	0.90047	0.89907	0.89826	0.89727	0.89587	0.89347	0.89267
r97	0.90127	0.89987	0.89907	0.89822	0.89727	0.89477	0.89394
r98	0.90204	0.90067	0.89987	0.89907	0.89822	0.89573	0.89493
r99	0.90278	0.90147	0.90067	0.89987	0.89907	0.89667	0.89587
r100	0.90354	0.90227	0.90147	0.90067	0.89987	0.89801	0.89667





When risk aversion increases, at every state-space point, the household wants to save more.

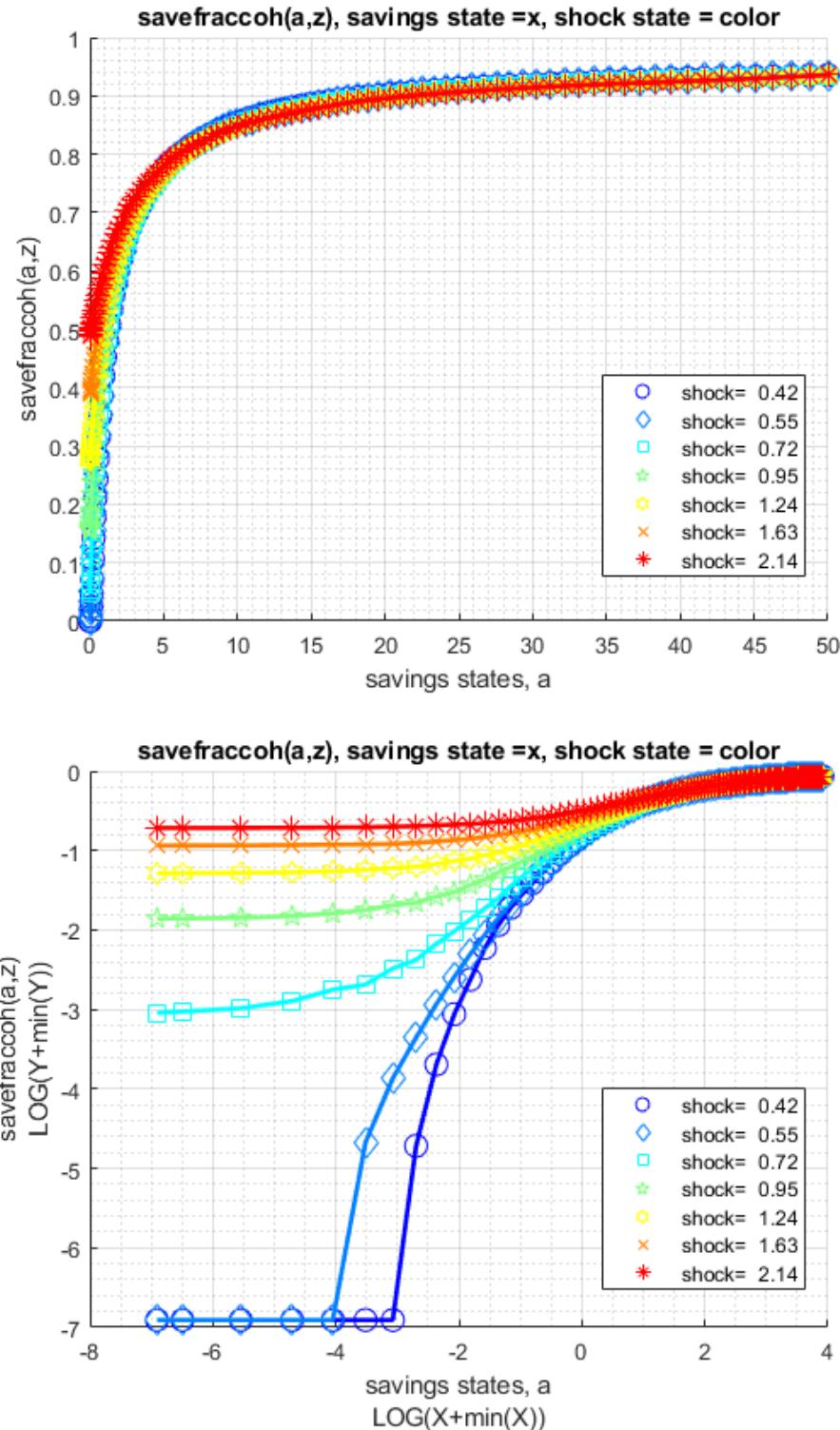
```
% Higher Risk Aversion
mp_params('fl_crra') = 5;
ff_vfi_az_mzoom_loop(mp_params, mp_support);

Elapsed time is 88.697274 seconds.
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefvar
	-	---	----	-----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	700	100	7	502.6	0.718	0.25437	0.35427

```
xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx
   c1      c2      c3      c4      c5      c6      c7
   -----  -----  -----  -----  -----  -----  -----
r1       0       0    0.04674  0.15532  0.27563  0.39047  0.48771
r2       0       0    0.047493  0.15525  0.27563  0.39101  0.48771
r3       0       0    0.049541  0.15685  0.27693  0.39127  0.48834
r4       0       0    0.054343  0.16018  0.27883  0.39287  0.48923
r5       0       0    0.062848  0.16566  0.28272  0.39528  0.49071
r96     0.93269  0.93251  0.93189  0.93108  0.93014  0.92988  0.92968
r97     0.93349  0.93322  0.93269  0.93189  0.93107  0.93104  0.93108
r98     0.93429  0.93349  0.93347  0.93269  0.93189  0.93189  0.93269
r99     0.93507  0.93429  0.93424  0.93349  0.93331  0.93349  0.93429
r100    0.93575  0.93509  0.93507  0.93488  0.93491  0.93509  0.93587
```



1.5.6 Test FF_VFI_AZ_MZOOM_LOOP with Higher Uncertainty

Increase the standard deviation of the Shock.

```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {'savefraccoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {};
```

```
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 150;
mp_params('it_z_n') = 15;
mp_params('fl_a_max') = 50;
mp_params('st_grid_type') = 'grid_powerspace';
```

Lower standard deviation of shock:

```
% Lower Risk Aversion
mp_params('fl_shk_std') = 0.10;
ff_vfi_az_mzoom_loop(mp_params, mp_support);
```

Elapsed time is 304.022067 seconds.

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coef
	-	---	----	-----	---	---	-----	-----	-----	-----
savefraccoh	1	1	2	2250	150	15	1507.2	0.66985	0.28667	0.42

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c11	c12	c13
	-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0	0.13838	0.18479	0.23021
r2	0	0	0	0	0	0.13838	0.18479	0.23027
r3	0	0	0	0	0	0.13894	0.18526	0.23041
r4	0	0	0	0	0	0.13987	0.18606	0.23121
r5	0	0	0	0	0	0.13998	0.18719	0.23201
r146	0.92348	0.92348	0.92328	0.92268	0.92268	0.92085	0.92028	0.92028
r147	0.9242	0.92398	0.92348	0.92348	0.92337	0.92108	0.92108	0.92097
r148	0.92428	0.92428	0.92428	0.92408	0.92348	0.92188	0.92171	0.92108
r149	0.92508	0.92497	0.92478	0.92428	0.92428	0.92241	0.92188	0.92188
r150	0.92565	0.92508	0.92508	0.92507	0.92485	0.92268	0.92268	0.92254

Higher shock standard deviation: low shock high asset save more, high shock more asset save less, high shock low asset save more:

```
% Higher Risk Aversion
mp_params('fl_shk_std') = 0.40;
ff_vfi_az_mzoom_loop(mp_params, mp_support);
```

Elapsed time is 304.175092 seconds.

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coef
	-	---	----	-----	---	---	-----	-----	-----	-----
savefraccoh	1	1	2	2250	150	15	1685.2	0.74898	0.22908	0.30

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c11	c12	c13
	-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0	0.52613	0.61256	0.68259
r2	0	0	0	0	0	0.52613	0.61256	0.68259

r3	0	0	0	0	0	0.52613	0.61256	0.68259
r4	0	0	0	0	0	0.52682	0.61256	0.68259
r5	0	0	0	0	0	0.52693	0.61309	0.68259
r146	0.92948	0.92925	0.92828	0.92805	0.92737	0.92263	0.92348	0.92577
r147	0.93017	0.92948	0.92868	0.92828	0.92748	0.92348	0.92428	0.92668
r148	0.93028	0.93005	0.92948	0.92891	0.92827	0.92428	0.92587	0.92799
r149	0.93091	0.93028	0.92948	0.92931	0.92828	0.92574	0.92668	0.92904
r150	0.93108	0.93082	0.93027	0.92948	0.92868	0.92668	0.92814	0.93008

1.6 FF_VFI_AZ_MZOOM_VEC Savings Vectorized Exact (VALUE) Examples

Go back to fan's MEconTools Toolbox ([bookdown](#)), Matlab Code Examples Repository ([bookdown](#)), or Math for Econ with Matlab Repository ([bookdown](#)).

This is the example vignette for function:[ff_vfi_az_mzoom_vec](#) from the [MEconTools Package](#). This function solves the dynamic programming problem for a (a,z) model. The state-space is on a grid, but choice grids are in terms of percentage of resources to save and solved exactly.

This is a **vectorized** code for **continuous** choices, solved with the **mzoom** algorithm. In contrast to the **bisection** based solution, this is slower, but this does not rely on first order conditions.

Links to Other Code:

Core Savings/Borrowing Dynamic Programming Solution Functions that are functions in the [MEconTools Package](#) :

- Common Choice and States Grid : [ff_vfi_az_loop](#)
- Common Choice and States Grid : [ff_vfi_az_vec](#)
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand, rely on FOC, :[ff_vfi_az_bisec_loop](#)
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand, rely on FOC : [ff_vfi_az_bisec_vec](#)
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand, VALUE comparison, :[ff_vfi_az_mzoom_loop](#)
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand, VALUE comparison, : [ff_vfi_az_mzoom_vec](#)

1.6.1 Test FF_VFI_AZ_MZOOM_VEC Defaults

Call the function with defaults. By default, shows the asset policy function summary. Model parameters can be changed by the mp_params.

```
%mp_params
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('fl_crta') = 1.5;
mp_params('fl_beta') = 0.94;
% call function
ff_vfi_az_mzoom_vec(mp_params);
```

Elapsed time is 6.126702 seconds.

```
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

i	idx	ndim	numel	rowN	colN	sum	mean	std	coefvari	min
-	---	----	-----	----	----	-----	-----	-----	-----	-----
ap	1	1	2	700	100	7	9861.5	14.088	14.386	1.0212

xxx TABLE:ap xxxxxxxxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6	c7
	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0.05343	0.25568	0.60598	1.1155
r2	0	0	0	0.053451	0.25571	0.60652	1.1161
r3	0	0	0	0.056468	0.25574	0.60897	1.1174
r4	0	0	0	0.061232	0.25995	0.61042	1.1238
r5	0	0	0	0.065929	0.2689	0.61091	1.1323
r96	43.387	43.517	43.7	43.922	44.221	44.657	45.225
r97	44.562	44.694	44.876	45.095	45.392	45.847	46.394
r98	45.758	45.89	46.071	46.287	46.583	47.037	47.596
r99	46.972	47.103	47.285	47.5	47.794	48.247	48.812
r100	48.183	48.337	48.518	48.732	49.025	49.478	50.115

1.6.2 Test FF_VFI_AZ_MZOOM_VEC Speed Tests

Call the function with defaults. By default, shows the asset policy function summary. Model parameters can be changed by the mp_params.

```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_timer') = true;
mp_support('ls_ffcmd') = {};
% A grid 50, shock grid 5:
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 50;
mp_params('it_z_n') = 5;
ff_vfi_az_mzoom_vec(mp_params, mp_support);
```

Elapsed time is 1.996365 seconds.

```
% A grid 750, shock grid 15:
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 750;
mp_params('it_z_n') = 15;
ff_vfi_az_mzoom_vec(mp_params, mp_support);
```

Elapsed time is 337.171768 seconds.

```
% A grid 600, shock grid 45:
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 600;
mp_params('it_z_n') = 45;
ff_vfi_az_mzoom_vec(mp_params, mp_support);
```

Elapsed time is 1758.273287 seconds.

1.6.3 Test FF_VFI_AZ_MZOOM_VEC Control Outputs

Run the function first without any outputs, but only the timer.

```
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 50;
mp_params('it_z_n') = 5;
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_timer') = true;
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
```

```
mp_support('ls_ffcmd') = {};
ff_vfi_az_mzoom_vec(mp_params, mp_support);
```

Elapsed time is 1.091918 seconds.

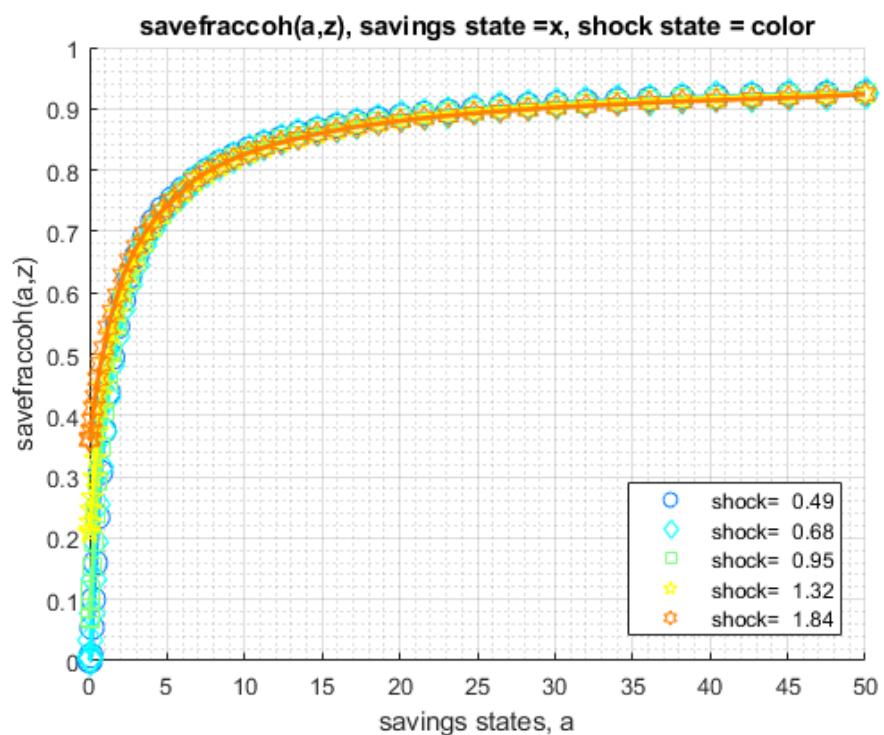
Run the function and show policy function for savings choice. For ls_ffcmd, ls_ffsna, ls_ffgrh, can include these: 'v', 'ap', 'c', 'y', 'coh', 'savefraccoh'. These are value, aprime savings choice, consumption, income, cash on hand, and savings fraction as cash-on-hand.

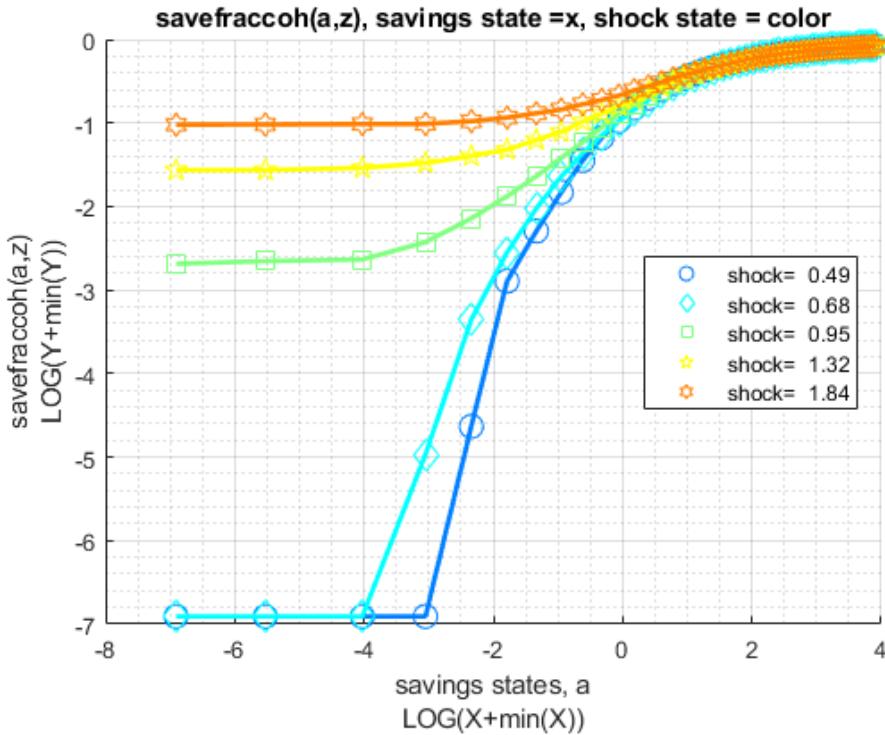
```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
% ls_ffcmd: summary print which outcomes
mp_support('ls_ffcmd') = {};
% ls_ffsna: detail print which outcomes
mp_support('ls_ffsna') = {'savefraccoh'};
% ls_ffgrh: graphical print which outcomes
mp_support('ls_ffgrh') = {'savefraccoh'};
ff_vfi_az_mzoom_vec(mp_params, mp_support);
```

Elapsed time is 1.090424 seconds.

group	a	mean_z_0_4858	mean_z_0_67798	mean_z_0_9462	mean_z_1_3205	mean_z_
1	0	0	0	0.067148	0.2084	0.3
2	0.002975	0	0	0.069345	0.20826	0.3
3	0.016829	0	0	0.070749	0.2136	0.3
4	0.046375	0	0.0059631	0.08732	0.22641	0.3
5	0.095198	0.008725	0.033935	0.11637	0.24674	0.
6	0.1663	0.054327	0.077152	0.15198	0.26635	0.3
7	0.26234	0.099882	0.13131	0.1936	0.29922	0.4
8	0.38568	0.15954	0.1928	0.24107	0.33005	0.4
9	0.53852	0.23411	0.25482	0.29164	0.37407	0.
10	0.72291	0.30704	0.31604	0.34806	0.41148	0.4
11	0.94076	0.37567	0.37487	0.40768	0.44925	0.5
12	1.1939	0.43849	0.42939	0.4573	0.48691	0.5
13	1.484	0.49491	0.48129	0.50332	0.53253	0.5
14	1.8128	0.54486	0.53013	0.54642	0.56773	0.5
15	2.1817	0.58868	0.57335	0.58545	0.60016	0.6
16	2.5924	0.6271	0.61254	0.62056	0.63057	0.6
17	3.0463	0.66058	0.6468	0.65237	0.65884	0.6
18	3.5449	0.69019	0.67699	0.68069	0.68379	0.6
19	4.0894	0.71615	0.70375	0.7058	0.70719	0.
20	4.6813	0.73661	0.72701	0.72843	0.72781	0.7
21	5.3218	0.75302	0.7481	0.74821	0.74661	0.7
22	6.0121	0.76912	0.76622	0.76622	0.76342	0.7
23	6.7536	0.78503	0.78285	0.78223	0.77885	0.7
24	7.5474	0.79943	0.79703	0.79623	0.79223	0.7
25	8.3948	0.81264	0.81024	0.8093	0.80504	0.8
26	9.2967	0.82384	0.82198	0.82064	0.81634	0.8
27	10.254	0.83447	0.83225	0.83065	0.82653	0.8
28	11.269	0.84345	0.84174	0.84025	0.83545	0.8
29	12.342	0.85185	0.85017	0.84865	0.84417	0.8
30	13.473	0.85962	0.85746	0.85642	0.85178	0.8
31	14.665	0.86626	0.86466	0.86306	0.85873	0.8
32	15.918	0.87226	0.87066	0.86959	0.86504	0.8
33	17.233	0.87786	0.87626	0.87529	0.87146	0.8
34	18.611	0.88332	0.88182	0.88026	0.87766	0.8

35	20.053	0.888	0.88656	0.88507	0.88267	0.8
36	21.56	0.89187	0.89087	0.88947	0.88825	0.8
37	23.133	0.89587	0.89484	0.89347	0.89256	0.8
38	24.773	0.8997	0.89827	0.89727	0.89587	0.8
39	26.481	0.903	0.90147	0.90066	0.89964	0.8
40	28.258	0.90601	0.90467	0.90376	0.90278	0.8
41	30.104	0.90881	0.9077	0.90628	0.90547	0.9
42	32.021	0.91137	0.91035	0.90908	0.90838	0.9
43	34.01	0.91377	0.91275	0.91148	0.91068	0.9
44	36.07	0.91595	0.91468	0.91388	0.91308	0.9
45	38.204	0.91788	0.91708	0.91617	0.91531	0.9
46	40.412	0.91948	0.91868	0.91788	0.91708	0.9
47	42.695	0.92168	0.92085	0.91998	0.91915	0.9
48	45.053	0.92331	0.92251	0.92171	0.92091	0.9
49	47.488	0.92485	0.92408	0.92331	0.92254	0.
50	50	0.92588	0.92555	0.92485	0.92423	0.9





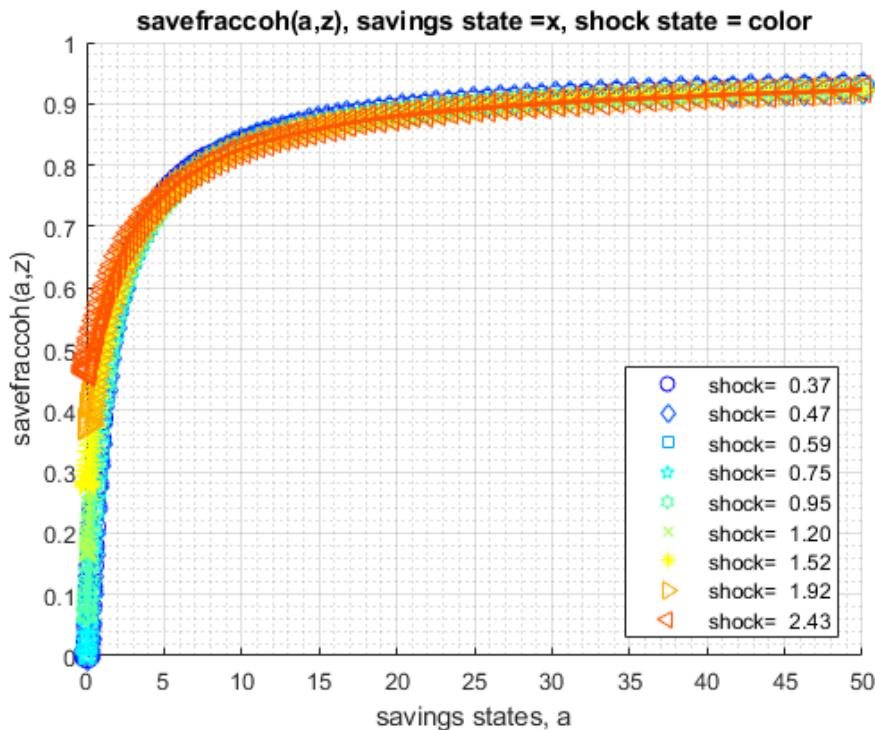
Run the function and show summaries for savings and fraction of coh saved:

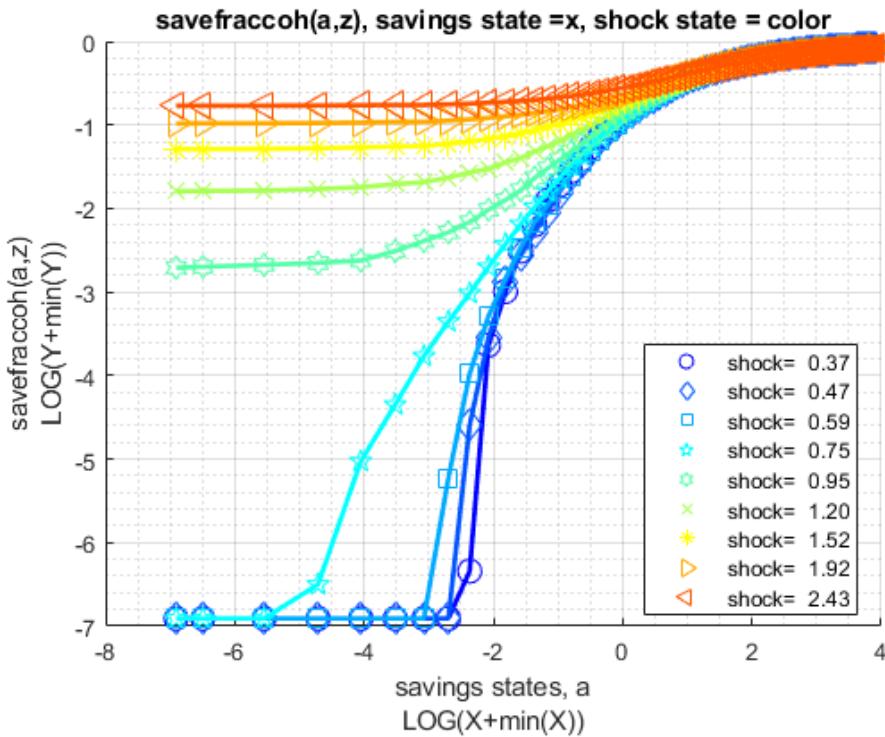
```
%mp_params
mp_params = containers.Map('KeyType','char', 'ValueType','any');
% mp_params('fl_crra') = 1.5;
% mp_params('fl_beta') = 0.94;
mp_params('it_a_n') = 100;
mp_params('it_z_n') = 9;
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
% ls_ffcmd: summary print which outcomes
mp_support('ls_ffcmd') = {};
% ls_ffsna: detail print which outcomes
mp_support('ls_ffsna') = {'savefraccoh'};
% ls_ffgrh: graphical print which outcomes
mp_support('ls_ffgrh') = {'savefraccoh'};
% call function
ff_vfi_az_mzoom_vec(mp_params, mp_support);

Elapsed time is 5.173849 seconds.
xxx ff_vfi_az_vec, outcome=savefraccoh xxxxxxxxxxxxxxxxxxxxxxxxx
group      a      mean_z_0_36853      mean_z_0_46648      mean_z_0_59047      mean_z_0_74742
-----  -----
1          0          0          0          0          0
2        0.00051272        0          0          0          0
3        0.0029004        0          0          0          0
4        0.0079925        0          0          0        0.00050216
5        0.016407        0          0          0        0.005563
6        0.028662        0          0          0        0.011926
7        0.045213        0          0          0        0.022095
8        0.06647         0          0        0.0043625        0.033935
9        0.092813     0.00076108     0.0091251     0.017748        0.047979
```

10	0.12459	0.02539	0.027791	0.036336	0.066347
11	0.16214	0.049062	0.054743	0.057497	0.087289
12	0.20576	0.080353	0.076351	0.084213	0.11115
13	0.25576	0.11036	0.10076	0.11357	0.13677
14	0.31242	0.14798	0.12866	0.14076	0.16483
15	0.37601	0.17839	0.16439	0.16895	0.194
16	0.4468	0.2098	0.20032	0.1988	0.22401
17	0.52503	0.24246	0.23721	0.23371	0.25482
18	0.61095	0.28123	0.27422	0.26803	0.28577
19	0.7048	0.31861	0.30964	0.30224	0.31644
20	0.8068	0.35352	0.34406	0.33561	0.34646
21	0.91719	0.38727	0.37774	0.36766	0.37639
22	1.0362	0.42001	0.40688	0.39888	0.40495
23	1.164	0.4501	0.43289	0.42881	0.43266
24	1.3008	0.47851	0.45746	0.45719	0.45922
25	1.4468	0.50572	0.48514	0.48371	0.48451
26	1.6023	0.53093	0.51118	0.50952	0.50892
27	1.7673	0.55214	0.53571	0.53333	0.53173
28	1.9422	0.57052	0.55854	0.55614	0.55374
29	2.127	0.58782	0.58031	0.57735	0.57415
30	2.3221	0.60768	0.60016	0.59758	0.59375
31	2.5275	0.62577	0.61947	0.61496	0.61226
32	2.7434	0.64351	0.63697	0.63101	0.62956
33	2.97	0.65976	0.65338	0.64537	0.64591
34	3.2075	0.67458	0.66898	0.66058	0.66124
35	3.456	0.68919	0.68379	0.67538	0.67538
36	3.7158	0.7022	0.69739	0.68939	0.68928
37	3.9869	0.7146	0.7098	0.7022	0.70205
38	4.2696	0.72668	0.7218	0.7146	0.7138
39	4.564	0.73741	0.73341	0.7262	0.7254
40	4.8702	0.74798	0.74381	0.73711	0.73581
41	5.1884	0.75768	0.75382	0.74727	0.74581
42	5.5188	0.76679	0.7618	0.75684	0.75542
43	5.8615	0.77502	0.76862	0.76542	0.76422
44	6.2166	0.78303	0.77658	0.77422	0.77262
45	6.5844	0.79063	0.78452	0.78223	0.78063
46	6.9649	0.79783	0.79196	0.78983	0.78823
47	7.3583	0.80499	0.79863	0.79695	0.79543
48	7.7647	0.81024	0.80566	0.80343	0.80231
49	8.1844	0.81504	0.81184	0.81003	0.80862
50	8.6173	0.81984	0.81744	0.81584	0.81424
51	9.0637	0.82544	0.82351	0.82144	0.82031
52	9.5237	0.83065	0.82881	0.82664	0.82544
53	9.9975	0.83545	0.83385	0.83217	0.83065
54	10.485	0.84025	0.83863	0.83697	0.83545
55	10.987	0.84494	0.84315	0.84155	0.84023
56	11.502	0.84919	0.84705	0.84585	0.84425
57	12.032	0.85319	0.85156	0.85002	0.84785
58	12.577	0.85666	0.85506	0.85396	0.85174
59	13.136	0.86064	0.85906	0.85746	0.85506
60	13.709	0.86386	0.86226	0.86122	0.85826
61	14.298	0.86706	0.86596	0.86461	0.86138
62	14.901	0.87052	0.86906	0.86746	0.86464
63	15.519	0.87306	0.87215	0.87066	0.86746
64	16.152	0.87626	0.87466	0.87378	0.87066
65	16.801	0.87866	0.87779	0.87626	0.8736
66	17.465	0.88163	0.88026	0.87923	0.87626
67	18.144	0.88409	0.88267	0.88179	0.87866

68	18.839	0.88646	0.88507	0.88422	0.88107
69	19.55	0.88867	0.88747	0.88653	0.88347
70	20.277	0.89087	0.88947	0.88867	0.88587
71	21.02	0.89267	0.89187	0.89087	0.88787
72	21.778	0.89493	0.89347	0.89267	0.89027
73	22.553	0.89667	0.89582	0.89487	0.89187
74	23.345	0.89827	0.89747	0.89667	0.89422
75	24.152	0.90034	0.89907	0.89827	0.89587
76	24.977	0.90204	0.90111	0.89987	0.89747
77	25.818	0.90361	0.90274	0.90147	0.89907
78	26.675	0.90515	0.90387	0.90307	0.90067
79	27.55	0.90628	0.90547	0.90467	0.90227
80	28.441	0.90788	0.90708	0.90547	0.90387
81	29.35	0.90908	0.9086	0.90708	0.90547
82	30.276	0.91068	0.90988	0.90825	0.90697
83	31.219	0.91195	0.91121	0.90908	0.90828
84	32.179	0.91308	0.91228	0.91035	0.90958
85	33.157	0.91388	0.91361	0.91148	0.91068
86	34.153	0.91543	0.91468	0.91228	0.91198
87	35.166	0.91628	0.91548	0.9138	0.91308
88	36.198	0.91708	0.91688	0.91468	0.91388
89	37.247	0.91851	0.91786	0.91548	0.91527
90	38.314	0.91946	0.91868	0.91691	0.91628
91	39.399	0.92028	0.91948	0.91788	0.91708
92	40.503	0.92108	0.92028	0.91868	0.91788
93	41.625	0.92188	0.92108	0.91948	0.91868
94	42.765	0.92268	0.92188	0.92028	0.92001
95	43.924	0.92348	0.92268	0.92108	0.92085
96	45.102	0.92428	0.92348	0.92188	0.92168
97	46.298	0.92508	0.92414	0.92268	0.92248
98	47.513	0.92588	0.92469	0.92348	0.92325
99	48.747	0.92668	0.92508	0.92428	0.92398
100	50	0.92737	0.9258	0.92508	0.92428





1.6.4 Test FF_VFI_AZ_MZOOM_VEC Change Interest Rate and Discount

Show only save fraction of cash on hand:

```

mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {'savefraccoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {};
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 750;
mp_params('it_z_n') = 9;
mp_params('fl_a_max') = 50;
mp_params('st_grid_type') = 'grid powerspace';

```

Solve the model with several different interest rates and discount factor:

```
% Lower Savings Incentives
mp_params('fl_beta') = 0.80;
mp_params('fl_r') = 0.01;
ff vfi az mzoom vec(mp_params, mp support);
```

Elapsed time is 37.005214 seconds.

xx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xx

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefv
	-	---	----	-----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	6750	750	9	3468.2	0.5138	0.27192	0.529

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6	c7	c8
	-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0	0	0	0.02073
r2	0	0	0	0	0	0	0	0.02073
r3	0	0	0	0	0	0	0	0.02073
r4	0	0	0	0	0	0	0	0.02073
r5	0	0	0	0	0	0	0	0.02073
r746	0.8008	0.79843	0.7959	0.79303	0.78983	0.78663	0.78303	0.77903
r747	0.80092	0.79855	0.79603	0.79303	0.79058	0.78713	0.78362	0.77953
r748	0.80102	0.79863	0.79615	0.7935	0.79063	0.78729	0.78378	0.77972
r749	0.80103	0.79863	0.79623	0.79369	0.79063	0.78743	0.78383	0.77983
r750	0.80103	0.79904	0.79623	0.79378	0.79063	0.78743	0.78383	0.77983

```
% Higher Savings Incentives
mp_params('fl_beta') = 0.95;
mp_params('fl_r') = 0.04;
ff_vfi_az_mzoom_vec(mp_params, mp_support);

Elapsed time is 159.606266 seconds.
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefv
	-	---	----	----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	6750	750	9	4667.7	0.6915	0.26685	0.38

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6	c7	c8
	-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0.0647	0.16668	0.27352	0.37327
r2	0	0	0	0	0.0647	0.16668	0.27352	0.37327
r3	0	0	0	0	0.064731	0.16668	0.27352	0.37327
r4	0	0	0	0	0.064731	0.16668	0.27355	0.37327
r5	0	0	0	0	0.064747	0.16671	0.27355	0.37327
r746	0.92657	0.92588	0.92508	0.92428	0.92348	0.92268	0.92235	0.92188
r747	0.92664	0.92588	0.92508	0.92428	0.92402	0.92318	0.92248	0.92188
r748	0.92668	0.92588	0.92508	0.92478	0.92411	0.92328	0.9226	0.92188
r749	0.92668	0.92588	0.92555	0.92488	0.9242	0.9234	0.92268	0.92254
r750	0.92668	0.92588	0.92565	0.92497	0.92427	0.92348	0.92268	0.92268

1.6.5 Test FF_VFI_AZ_MZOOM_VEC Changing Risk Aversion

Here, again, show fraction of coh saved in summary tabular form, but also show it graphically.

```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {'savefraccoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {'savefraccoh'};
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 100;
mp_params('it_z_n') = 7;
mp_params('fl_a_max') = 50;
mp_params('st_grid_type') = 'grid_powerspace';
```

Solve the model with different risk aversion levels, higher preferences for risk:

```
% Lower Risk Aversion
mp_params('fl_crra') = 0.5;
ff_vfi_az_mzoom_vec(mp_params, mp_support);
```

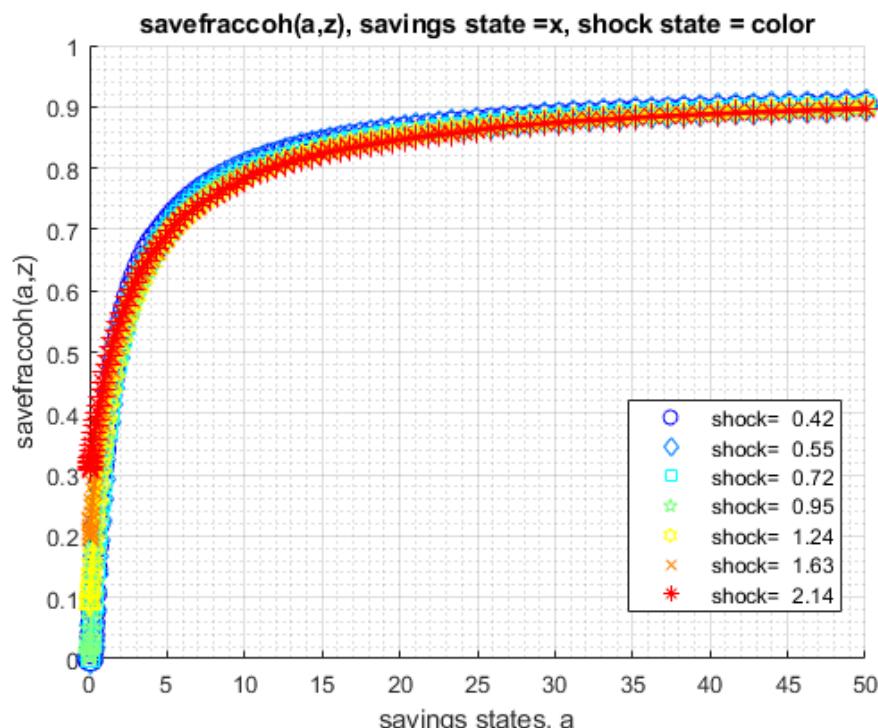
Elapsed time is 3.409484 seconds.

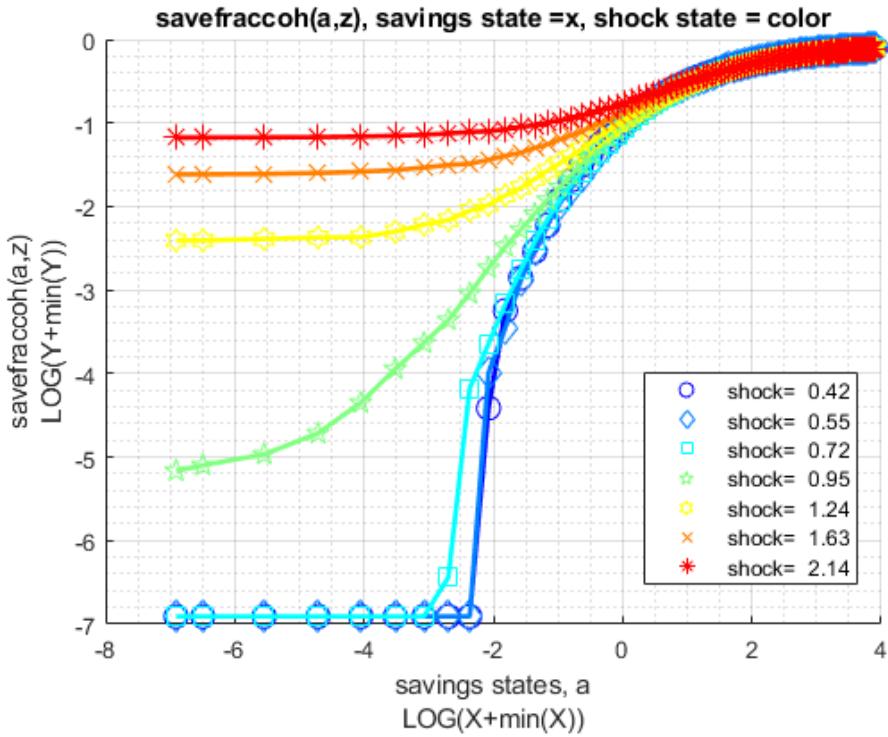
```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coef
	-	---	----	-----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	700	100	7	452.03	0.64575	0.28029	0.43

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6	c7
r1	0	0	0	0.0047077	0.089109	0.198	0.30781
r2	0	0	0	0.0051079	0.089156	0.198	0.30793
r3	0	0	0	0.0059631	0.090679	0.1988	0.30848
r4	0	0	0	0.0079639	0.092358	0.20109	0.30964
r5	0	0	0	0.011926	0.092758	0.20413	0.31171
r96	0.90047	0.89907	0.89826	0.89727	0.89587	0.89347	0.89267
r97	0.90127	0.89987	0.89907	0.89822	0.89727	0.89477	0.89394
r98	0.90204	0.90067	0.89987	0.89907	0.89822	0.89573	0.89493
r99	0.90278	0.90147	0.90067	0.89987	0.89907	0.89667	0.89587
r100	0.90354	0.90227	0.90147	0.90067	0.89987	0.89801	0.89667





When risk aversion increases, at every state-space point, the household wants to save more.

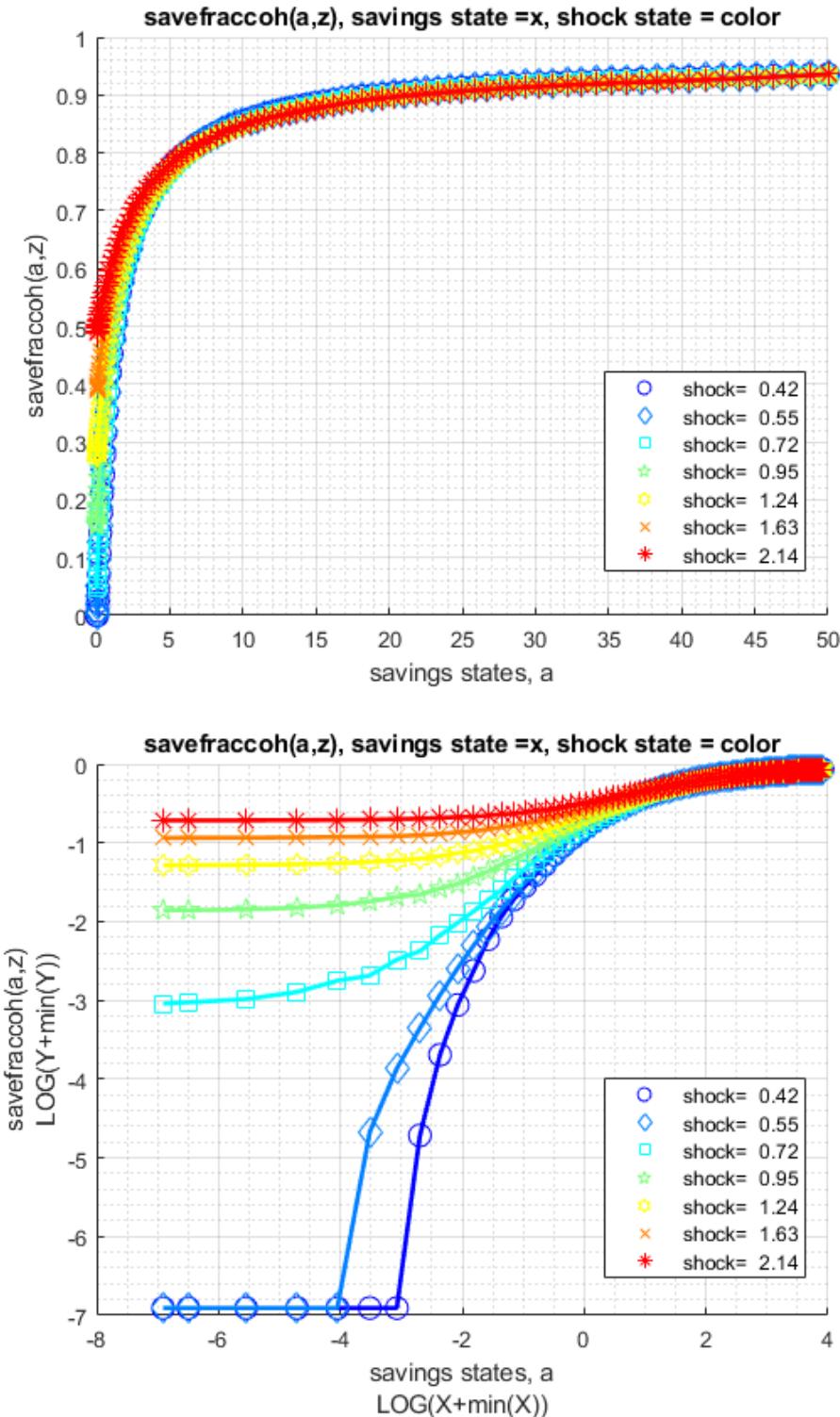
```
% Higher Risk Aversion
mp_params('fl_crra') = 5;
ff_vfi_az_mzoom_vec(mp_params, mp_support);

Elapsed time is 4.012888 seconds.
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefvar
	-	---	----	-----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	700	100	7	502.6	0.718	0.25437	0.35427

```
xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx
   c1      c2      c3      c4      c5      c6      c7
   -----  -----  -----  -----  -----  -----  -----
r1       0       0    0.04674  0.15532  0.27563  0.39047  0.48771
r2       0       0    0.047493  0.15525  0.27563  0.39101  0.48771
r3       0       0    0.049541  0.15685  0.27693  0.39127  0.48834
r4       0       0    0.054343  0.16018  0.27883  0.39287  0.48923
r5       0       0    0.062848  0.16566  0.28272  0.39528  0.49071
r96     0.93269  0.93251  0.93189  0.93108  0.93014  0.92988  0.92968
r97     0.93349  0.93322  0.93269  0.93189  0.93107  0.93104  0.93108
r98     0.93429  0.93349  0.93347  0.93269  0.93189  0.93189  0.93269
r99     0.93507  0.93429  0.93424  0.93349  0.93331  0.93349  0.93429
r100    0.93575  0.93509  0.93507  0.93488  0.93491  0.93509  0.93587
```



1.6.6 Test FF_VFI_AZ_MZOOM_VEC with Higher Uncertainty

Increase the standard deviation of the Shock.

```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
mp_support('ls_ffcmd') = {'savefraccoh'};
mp_support('ls_ffsna') = {};
mp_support('ls_ffgrh') = {};
```

```
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 150;
mp_params('it_z_n') = 15;
mp_params('fl_a_max') = 50;
mp_params('st_grid_type') = 'grid_powerspace';
```

Lower standard deviation of shock:

```
% Lower Risk Aversion
mp_params('fl_shk_std') = 0.10;
ff_vfi_az_mzoom_vec(mp_params, mp_support);
```

Elapsed time is 16.599473 seconds.

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coef
	-	---	----	-----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	2250	150	15	1507.2	0.66985	0.28667	0.42

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c11	c12	c13
	-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0	0.13838	0.18479	0.23021
r2	0	0	0	0	0	0.13838	0.18479	0.23027
r3	0	0	0	0	0	0.13894	0.18526	0.23041
r4	0	0	0	0	0	0.13987	0.18606	0.23121
r5	0	0	0	0	0	0.13998	0.18719	0.23201
r146	0.92348	0.92348	0.92328	0.92268	0.92268	0.92085	0.92028	0.92028
r147	0.9242	0.92398	0.92348	0.92348	0.92337	0.92108	0.92108	0.92097
r148	0.92428	0.92428	0.92428	0.92408	0.92348	0.92188	0.92171	0.92108
r149	0.92508	0.92497	0.92478	0.92428	0.92428	0.92241	0.92188	0.92188
r150	0.92565	0.92508	0.92508	0.92507	0.92485	0.92268	0.92268	0.92254

Higher shock standard deviation: low shock high asset save more, high shock more asset save less, high shock low asset save more:

```
% Higher Risk Aversion
mp_params('fl_shk_std') = 0.40;
ff_vfi_az_mzoom_vec(mp_params, mp_support);
```

Elapsed time is 16.323916 seconds.

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coef
	-	---	----	-----	----	----	-----	-----	-----	-----
savefraccoh	1	1	2	2250	150	15	1685.2	0.74898	0.22908	0.30

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c11	c12	c13
	-----	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0	0	0.52613	0.61256	0.68259
r2	0	0	0	0	0	0.52613	0.61256	0.68259

r3	0	0	0	0	0	0.52613	0.61256	0.68259
r4	0	0	0	0	0	0.52682	0.61256	0.68259
r5	0	0	0	0	0	0.52693	0.61309	0.68259
r146	0.92948	0.92925	0.92828	0.92805	0.92737	0.92263	0.92348	0.92577
r147	0.93017	0.92948	0.92868	0.92828	0.92748	0.92348	0.92428	0.92668
r148	0.93028	0.93005	0.92948	0.92891	0.92827	0.92428	0.92587	0.92799
r149	0.93091	0.93028	0.92948	0.92931	0.92828	0.92574	0.92668	0.92904
r150	0.93108	0.93082	0.93027	0.92948	0.92868	0.92668	0.92814	0.93008

Chapter 2

Stationary Distribution

2.1 FF_DS_AZ_LOOP Dynamic Savings Loop Discrete Distribution

Go back to fan's MEconTools Toolbox ([bookdown](#)), Matlab Code Examples Repository ([bookdown](#)), or Math for Econ with Matlab Repository ([bookdown](#)).

This is the example vignette for function: `ff_ds_az_loop` from the **MEconTools Package**. F(a,z) discrete probability mass function given policy function solution with discretized savings choices.

- Distribution for Common Choice and States Grid : `ff_ds_az_loop`
- Distribution for States Grid + Continuous Exact Savings as Share of Cash-on-Hand : `ff_ds_az_cts_loop`

2.1.1 Test FF_DS_AZ_LOOP Defaults

Call the function with defaults. By default, shows the asset policy function summary. Model parameters can be changed by the mp_params.

```
%mp_params
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('fl_crqa') = 1.5;
mp_params('fl_beta') = 0.94;
% call function
ff_ds_az_loop(mp_params);
```

Elapsed time is 0.159342 seconds.

```
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      i     idx    ndim   numel   rowN   colN    sum   mean    std  coefvari  min
      -     ---    ----   -----   ----   ----   -----   ----   ----   -----
ap    1      1      2      700     100      7  9855.1  14.079  14.408  1.0234    0
      c1      c2      c3      c4      c5      c6      c7
      ----  -----  -----  -----  -----  -----  -----
r1      0      0      0  0.045213  0.25576  0.61095  1.0362
r2      0      0      0  0.045213  0.25576  0.61095  1.0362
r3      0      0      0  0.045213  0.25576  0.61095  1.0362
```

r4	0	0	0	0.06647	0.25576	0.61095	1.0362
r5	0	0	0	0.06647	0.25576	0.61095	1.164
r96	43.924	43.924	43.924	43.924	43.924	45.102	45.102
r97	45.102	45.102	45.102	45.102	45.102	46.298	46.298
r98	46.298	46.298	46.298	46.298	46.298	47.513	47.513
r99	47.513	47.513	47.513	47.513	47.513	48.747	48.747
r100	48.747	48.747	48.747	48.747	48.747	50	50

FF_DS_AZ_LOOP finished. Distribution took = 0.13388

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

CONTAINER NAME: mp_ddcmd ND Array (Matrix etc)

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefvari
	-	---	----	-----	----	----	---	-----	-----	-----
fa	1	1	2	100	100	1	1	0.01	0.016114	1.6114
faz	2	2	2	700	100	7	1	0.0014286	0.0035847	2.5093
fz	3	3	2	7	7	1	1	0.14286	0.11742	0.82196

xxx TABLE:fa xxxxxxxxxxxxxxxxx

c1

r1	0.121
r2	0.00034068
r3	0
r4	0.010458
r5	0.0048751
r96	1.1148e-21
r97	3.227e-22
r98	7.9165e-23
r99	1.4982e-23
r100	1.7037e-24

xxx TABLE:faz xxxxxxxxxxxxxxxxx

c1

c2

c3

c4

c5

c6

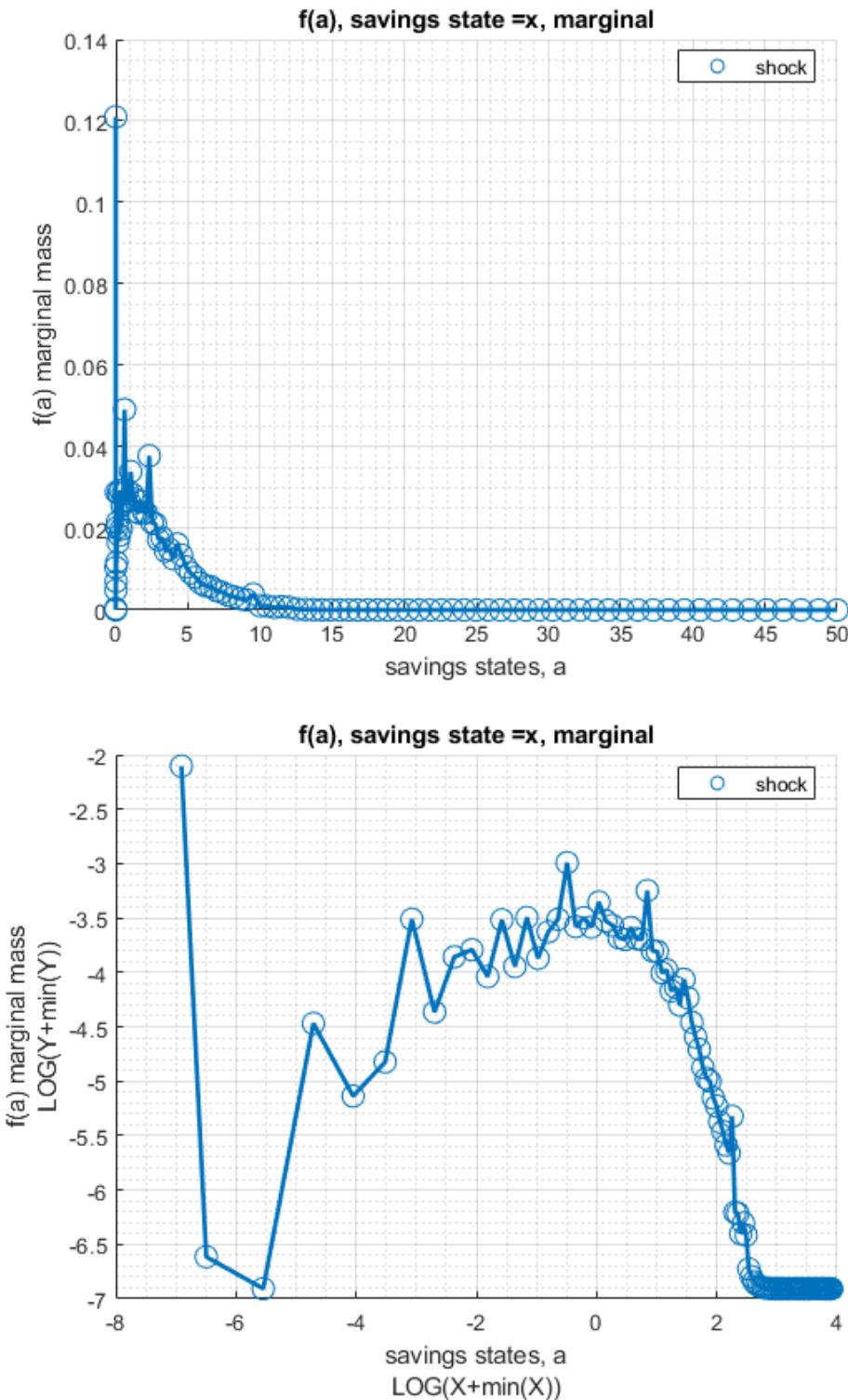
r1	0.0084023	0.03778	0.052693	0.018985	0.0029243	0.00020787	5.63
r2	0.00018105	0.0001207	3.3528e-05	4.9671e-06	4.1392e-07	1.8397e-08	3.40
r3	0	0	0	0	0	0	0
r4	0.00016518	0.002081	0.005593	0.0022334	0.00035834	2.6032e-05	7.1
r5	0.00021881	0.00067299	0.0026761	0.0011123	0.00018127	1.3278e-05	3.66
r96	1.7183e-25	2.8942e-24	2.2565e-23	1.0675e-22	3.1764e-22	4.9586e-22	1.68
r97	3.2228e-26	6.111e-25	5.3384e-24	2.7969e-23	9.0055e-23	1.4769e-22	5.10
r98	4.5065e-27	1.0023e-25	1.0174e-24	6.0677e-24	2.15e-23	3.7371e-23	1.31
r99	3.8775e-28	1.0954e-26	1.38e-25	9.8022e-25	3.9213e-24	7.3193e-24	2.61
r100	1.1692e-29	5.3148e-28	9.7109e-27	8.9563e-26	4.2252e-25	8.6574e-25	3.15

xxx TABLE:fz xxxxxxxxxxxxxxxxx

c1

r1	0.015625
r2	0.09375
r3	0.23438
r4	0.3125

r5	0.23438
r6	0.09375
r7	0.015625



2.1.2 Test FF_DS_AZ_LOOP Speed Tests

Call the function with different a and z grid size, print out speed:

```
mp_support = containers.Map('KeyType', 'char', 'ValueType', 'any');
mp_support('bl_timer') = true;
mp_support('ls_ffcmd') = {};
```

```

mp_support('ls_ddcmd') = {};
mp_support('ls_ddgrh') = {};
mp_support('bl_show_stats_table') = false;
% A grid 50, shock grid 5:
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 50;
mp_params('it_z_n') = 5;
ff_ds_az_loop(mp_params, mp_support);

Elapsed time is 0.025627 seconds.
FF_DS_AZ_LOOP finished. Distribution took = 0.066138

% A grid 100, shock grid 7:
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 100;
mp_params('it_z_n') = 7;
ff_ds_az_loop(mp_params, mp_support);

Elapsed time is 0.155714 seconds.
FF_DS_AZ_LOOP finished. Distribution took = 0.11763

% A grid 200, shock grid 9:
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 200;
mp_params('it_z_n') = 9;
ff_ds_az_loop(mp_params, mp_support);

Elapsed time is 0.332056 seconds.
FF_DS_AZ_LOOP finished. Distribution took = 0.32648

```

2.1.3 Test FF_DS_AZ_LOOP A grid 100 Shock grid 7

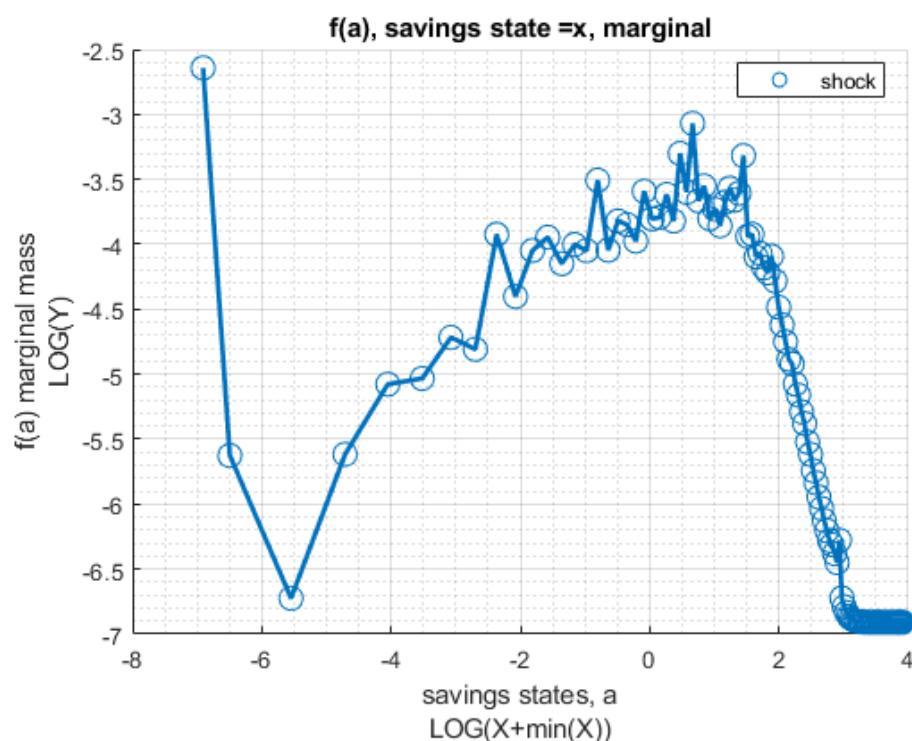
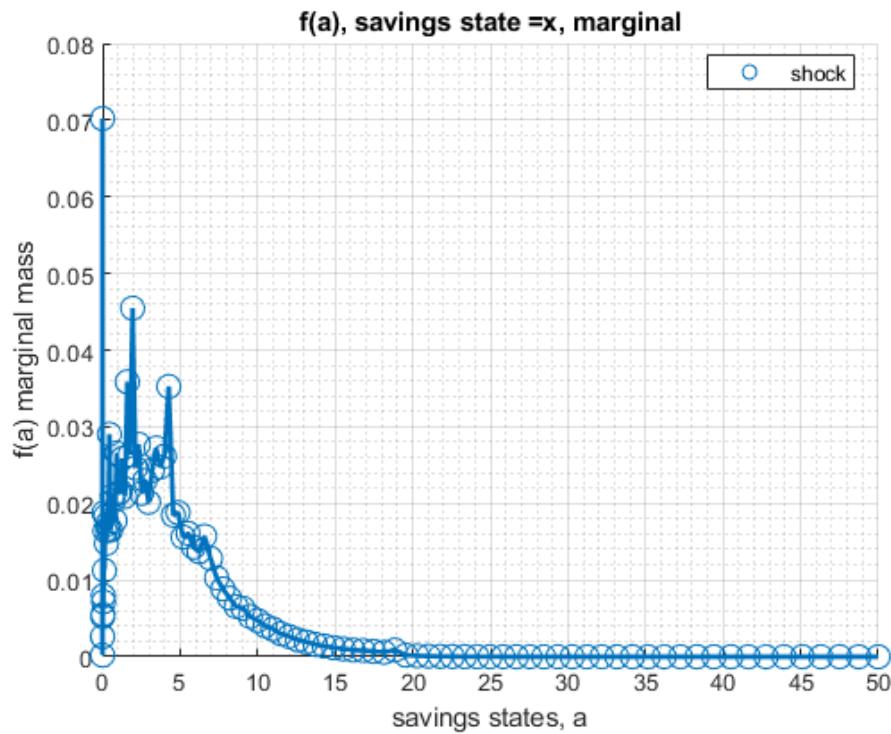
Call the function with different a and z grid size, print out speed:

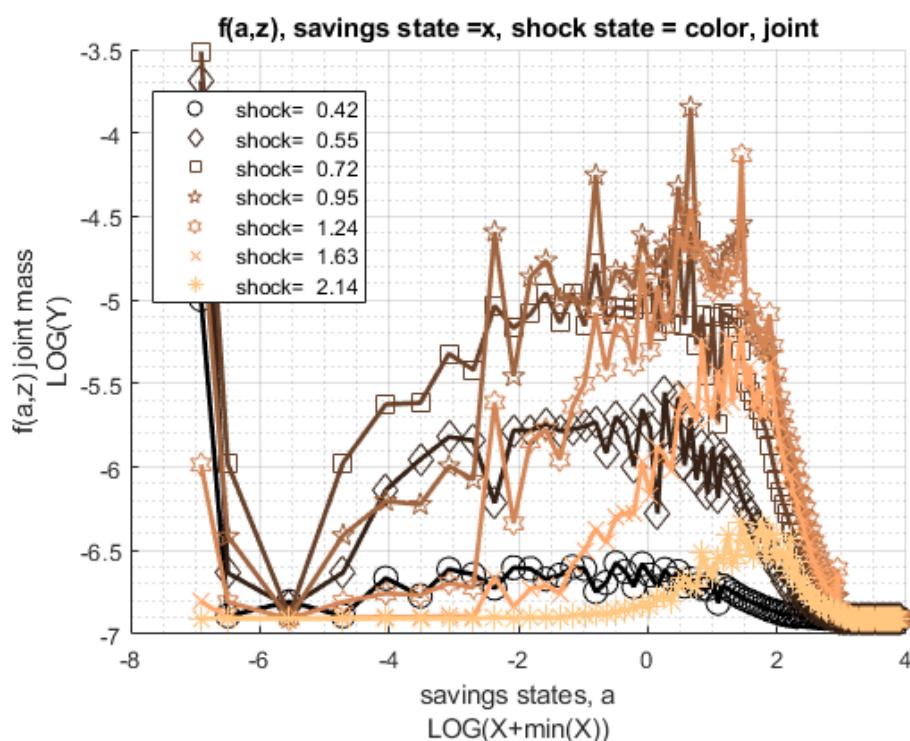
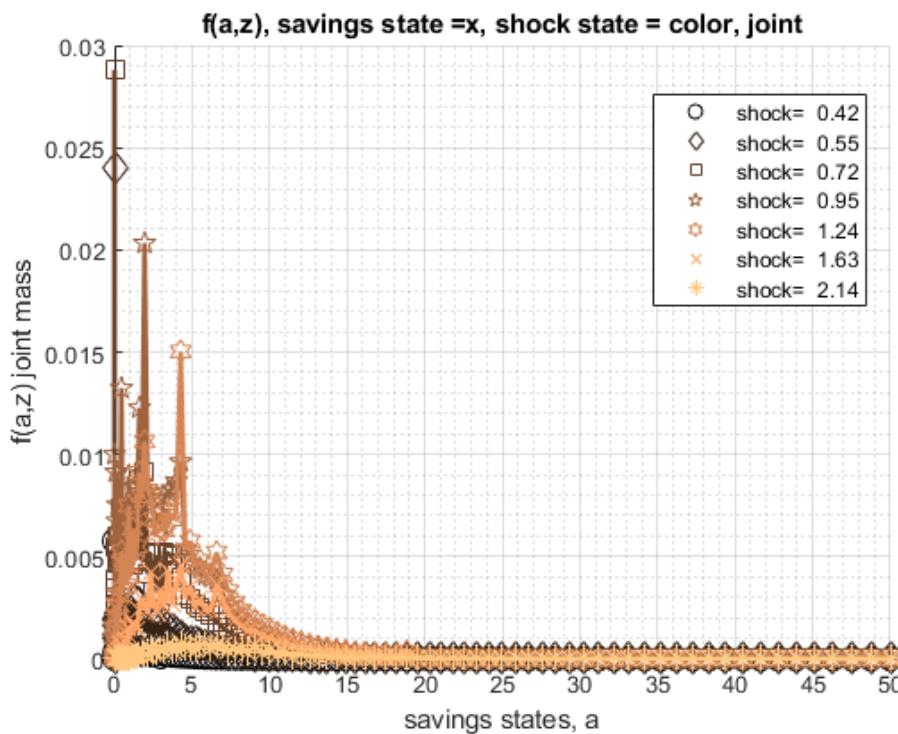
```

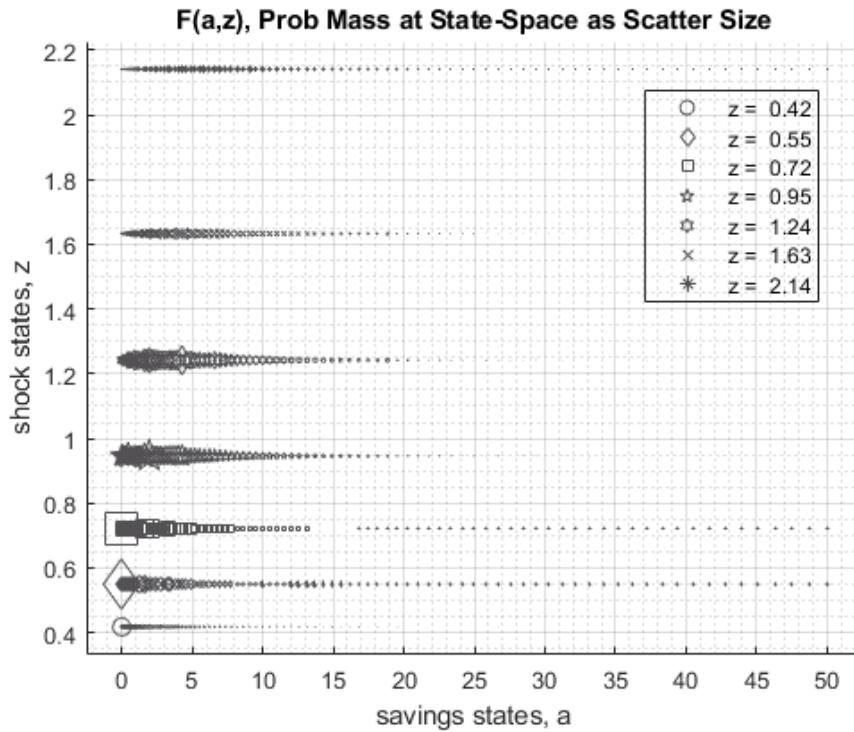
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_timer') = true;
mp_support('ls_ffcmd') = {};
mp_support('ls_ddcmd') = {};
mp_support('ls_ddgrh') = {'faz','fa'};
mp_support('bl_show_stats_table') = true;
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 100;
mp_params('it_z_n') = 7;
ff_ds_az_loop(mp_params, mp_support);

Elapsed time is 0.144655 seconds.
FF_DS_AZ_LOOP finished. Distribution took = 0.13625

```







xxx tb_outcomes: all stats xxx

OriginalVariableNames	ap	v	c	y	coh
{'mean'}	2.7094	6.6576	1.5089	1.5084	4.2183
{'sd'}	2.8976	2.0599	0.35843	0.52611	3.2096
{'coefofvar'}	1.0694	0.3094	0.23755	0.34879	0.76088
{'min'}	0	1.6927	0.58543	0.58543	0.58543
{'max'}	50	19.139	4.9969	4.9969	54.997
{'pYiso'}	0.070216	0	0	0	0
{'pYls0'}	0	0	0	0	0
{'pYgr0'}	0.92978	1	1	1	1
{'pYisMINY'}	0.070216	0.0057675	0.0057675	0.0057675	0.0057675
{'pYisMAXY'}	2.1143e-10	3.7149e-11	3.7149e-11	3.7149e-11	3.7149e-11
{'p0_01'}	0	1.6927	0.58543	0.58543	0.58543
{'p0_1'}	0	1.6927	0.58543	0.58543	0.58543
{'p1'}	0	2.7674	0.76855	0.61362	0.76855
{'p5'}	0	3.273	0.91608	0.77504	1.009
{'p10'}	0.06647	4.0961	1.0308	0.92803	1.1055
{'p20'}	0.37601	4.8781	1.2371	1.0319	1.555
{'p25'}	0.52503	5.2636	1.2781	1.0731	1.8354
{'p30'}	0.7048	5.4822	1.3424	1.1472	2.0866
{'p40'}	1.3008	6.0574	1.3953	1.3424	2.6774
{'p50'}	1.9422	6.542	1.4931	1.4023	3.3444
{'p60'}	2.5275	7.1265	1.6174	1.4954	4.1208
{'p70'}	3.456	7.657	1.6502	1.7803	5.1554
{'p75'}	3.9869	8.0469	1.733	1.824	5.7555
{'p80'}	4.564	8.4125	1.8179	1.8875	6.1793
{'p90'}	6.5844	9.3821	1.9734	2.3349	8.568
{'p95'}	8.1844	10.225	2.1388	2.4776	10.358
{'p99'}	13.136	11.834	2.3359	3.1677	15.511
{'p99_9'}	18.839	13.486	2.7733	3.4782	21.332
{'p99_99'}	21.778	14.354	3.0939	3.7505	24.78
{'fl_cov_ap'}	8.396	5.2587	0.88866	0.93721	9.2847

{'fl_cor_ap'}	}	1	0.88106	0.85565	0.61478	0.99833
{'fl_cov_v'}	}	5.2587	4.243	0.71989	0.93806	5.9786
{'fl_cor_v'}	}	0.88106	1	0.97505	0.86559	0.90428
{'fl_cov_c'}	}	0.88866	0.71989	0.12847	0.15253	1.0171
{'fl_cor_c'}	}	0.85565	0.97505	1	0.80886	0.88413
{'fl_cov_y'}	}	0.93721	0.93806	0.15253	0.2768	1.0897
{'fl_cor_y'}	}	0.61478	0.86559	0.80886	1	0.64534
{'fl_cov_coh'}	}	9.2847	5.9786	1.0171	1.0897	10.302
{'fl_cor_coh'}	}	0.99833	0.90428	0.88413	0.64534	1
{'fl_cov_savefraccoh'}		0.58458	0.453	0.079518	0.080824	0.6641
{'fl_cor_savefraccoh'}		0.7919	0.86321	0.8708	0.603	0.81215
{'fracByP0_01'}	}	0	0.0014664	0.0022377	0.0022385	0.00080043
{'fracByP0_1'}	}	0	0.0014664	0.0022377	0.0022385	0.00080043
{'fracByP1'}	}	0	0.0029302	0.01567	0.00403	0.0055106
{'fracByP5'}	}	0	0.021763	0.026172	0.02466	0.015702
{'fracByP10'}		0.0004071	0.050764	0.058937	0.05144	0.022123
{'fracByP20'}		0.0096198	0.1171	0.13549	0.11855	0.05416
{'fracByP25'}		0.017608	0.15851	0.17677	0.15694	0.074837
{'fracByP30'}		0.02761	0.19906	0.21973	0.19018	0.09783
{'fracByP40'}		0.071719	0.28454	0.3135	0.28477	0.15542
{'fracByP50'}		0.15388	0.38017	0.40577	0.38385	0.23227
{'fracByP60'}		0.21684	0.48325	0.51534	0.46249	0.31381
{'fracByP70'}		0.32573	0.59393	0.62048	0.57438	0.42716
{'fracByP75'}		0.39815	0.65416	0.68002	0.63899	0.4882
{'fracByP80'}		0.48482	0.72413	0.732	0.69931	0.55881
{'fracByP90'}		0.6819	0.84902	0.85906	0.8281	0.73338
{'fracByP95'}		0.79123	0.91664	0.92592	0.90812	0.83969
{'fracByP99'}		0.9433	0.98136	0.98418	0.97889	0.95655
{'fracByP99_9'}		0.99595	0.99805	0.99819	0.99776	0.99501
{'fracByP99_99'}		0.99934	0.99982	0.99985	0.9998	0.99938

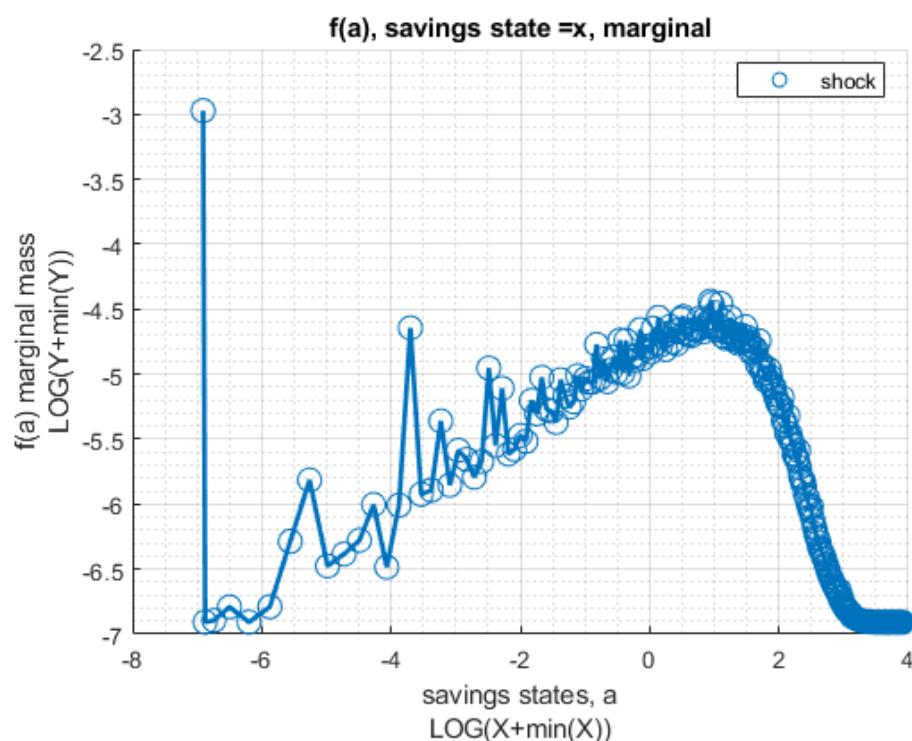
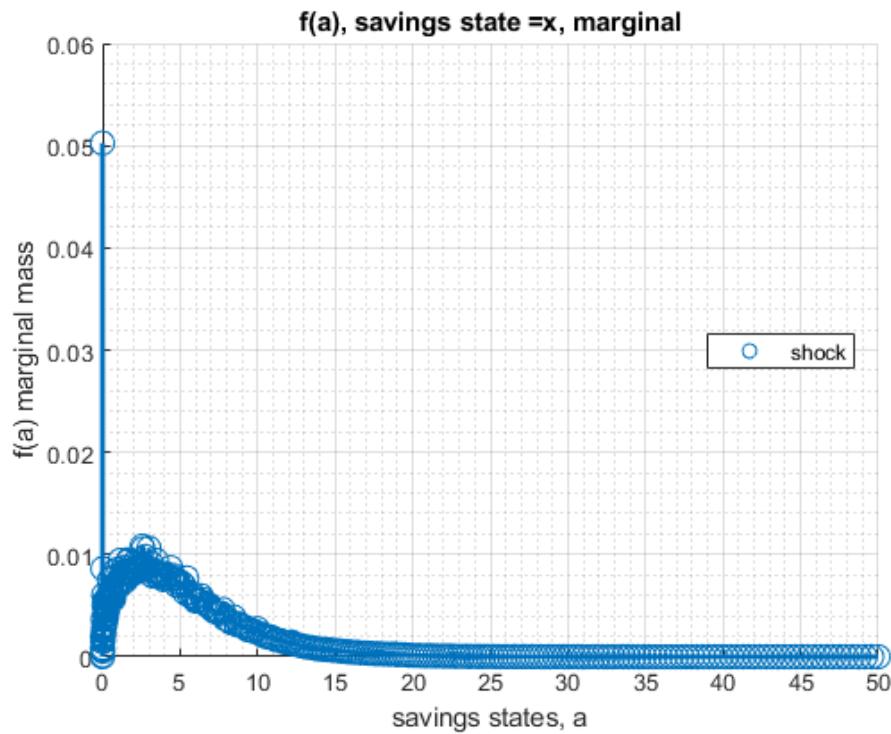
2.1.4 Test FF_DS_AZ_LOOP A grid 300 Shock Grid 25

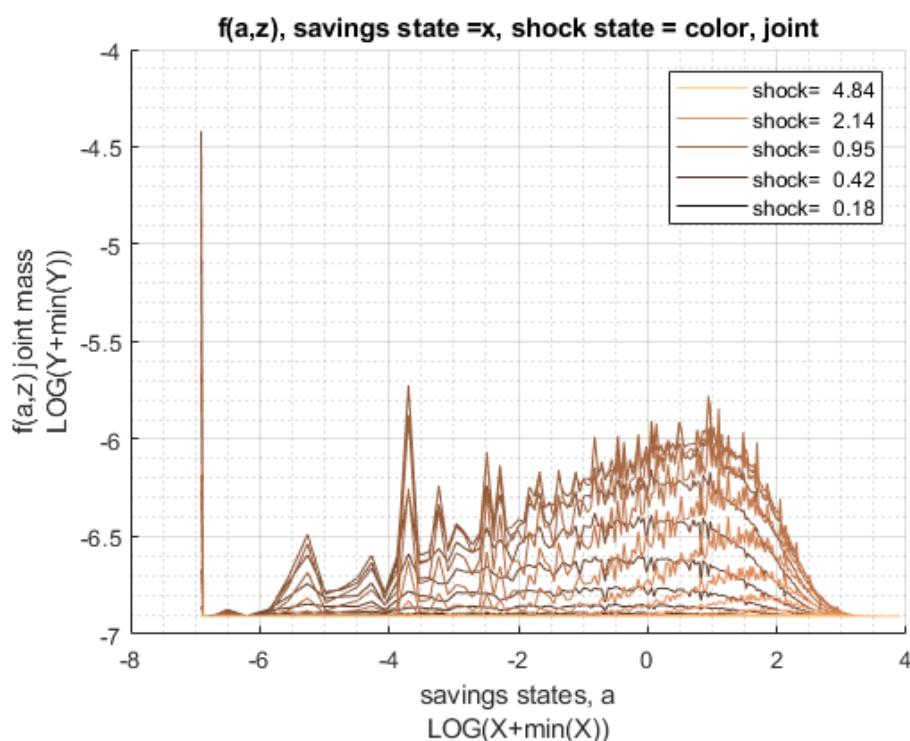
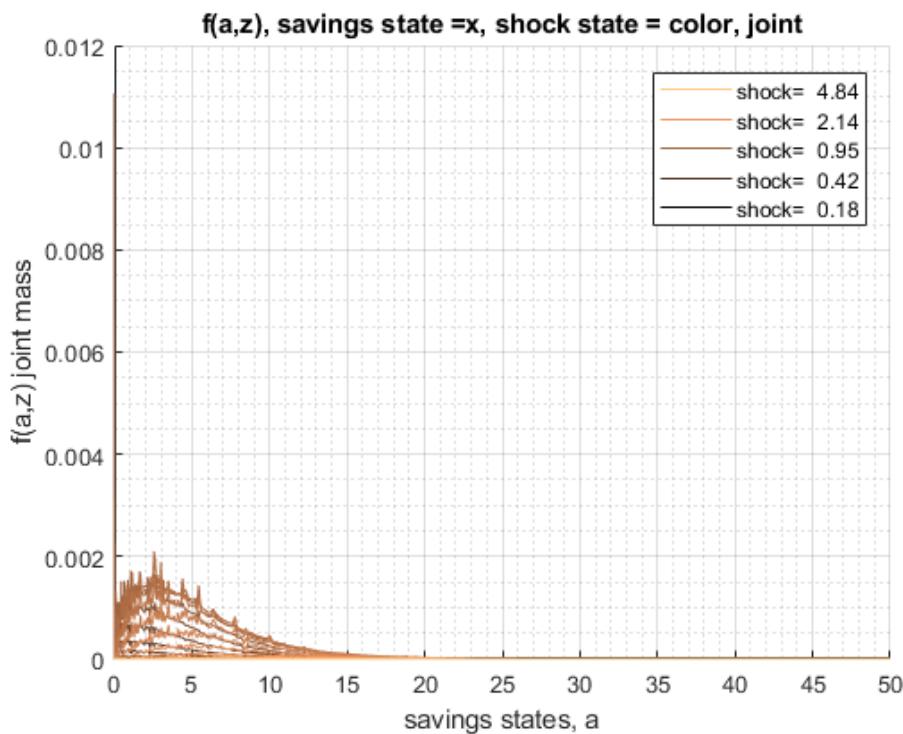
```

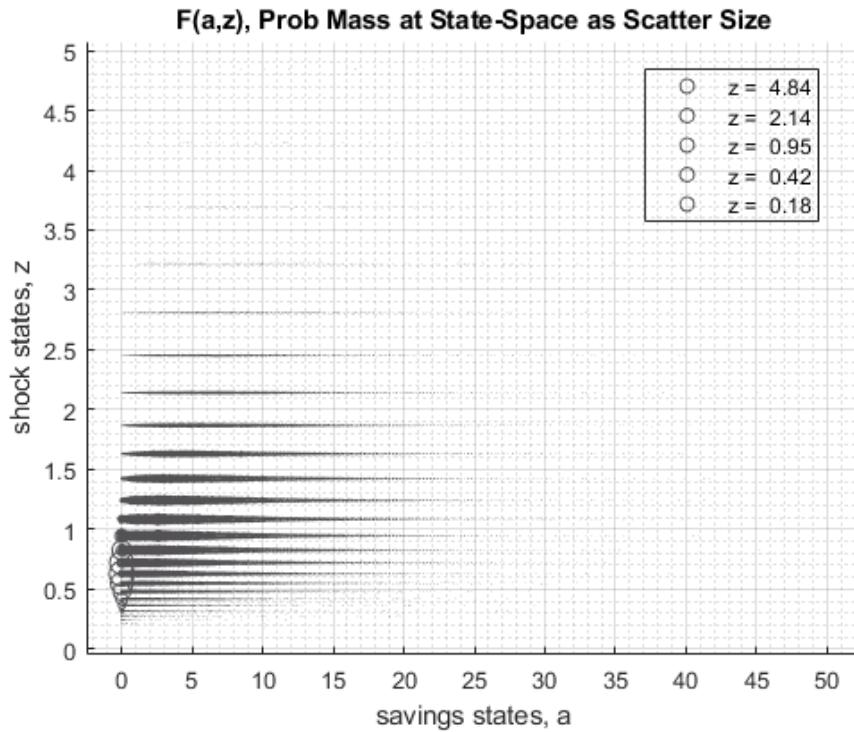
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_timer') = true;
mp_support('ls_ffcmd') = {};
mp_support('ls_ddcmd') = {};
mp_support('ls_ddgrh') = {'faz','fa'};
mp_support('bl_show_stats_table') = true;
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 300;
mp_params('it_z_n') = 25;
ff_ds_az_loop(mp_params, mp_support);

```

Elapsed time is 1.664355 seconds.
FF_DS_AZ_LOOP finished. Distribution took = 1.3793







xxx tb_outcomes: all stats xxx

OriginalVariableNames	ap	v	c	y	coh
{'mean'}	3.1835	6.9106	1.5286	1.5274	4.7121
{'sd'}	3.2831	2.152	0.35175	0.53521	3.5973
{'coefofvar'}	1.0313	0.31141	0.2301	0.35041	0.76341
{'min'}	0	-2.7621	0.25871	0.25871	0.25871
{'max'}	50	20.027	8.7798	8.7798	58.78
{'pYiso'}	0.050267	0	0	0	0
{'pYls0'}	0	7.4299e-05	0	0	0
{'pYgr0'}	0.94973	0.99993	1	1	1
{'pYisMINY'}	0.050267	3.1587e-08	3.1587e-08	3.1587e-08	3.1587e-08
{'pYisMAXY'}	2.3964e-09	9.6288e-14	9.6288e-14	9.6288e-14	9.6288e-14
{'p0_01'}	0	0.33524	0.44588	0.42089	0.44588
{'p0_1'}	0	1.0281	0.51088	0.51088	0.51088
{'p1'}	0	2.3294	0.67069	0.67069	0.67069
{'p5'}	0	3.531	0.9348	0.80006	1.0088
{'p10'}	0.10107	4.1808	1.0877	0.90775	1.2209
{'p20'}	0.48982	5.0629	1.248	1.0638	1.7564
{'p25'}	0.7256	5.3749	1.3048	1.157	2.0452
{'p30'}	0.97897	5.7085	1.3561	1.192	2.3425
{'p40'}	1.5756	6.2702	1.4389	1.3331	2.9951
{'p50'}	2.2184	6.8025	1.5235	1.4352	3.7422
{'p60'}	2.9972	7.3608	1.6237	1.5724	4.6044
{'p70'}	4.012	7.977	1.7017	1.7487	5.6899
{'p75'}	4.5871	8.3254	1.7349	1.8191	6.3522
{'p80'}	5.3173	8.7116	1.8227	1.9222	7.1504
{'p90'}	7.5009	9.7584	1.9829	2.2334	9.526
{'p95'}	9.6743	10.633	2.1133	2.5088	11.809
{'p99'}	14.854	12.286	2.3901	3.1545	17.176
{'p99_9'}	21.166	14.023	2.7913	3.9726	23.779
{'p99_99'}	26.803	15.357	3.0931	4.7968	29.914
{'fl_cov_ap'}	10.779	6.2944	1.019	1.0643	11.798

{'fl_cor_ap'}	}	1	0.89089	0.88234	0.60566	0.99894
{'fl_cov_v'}	}	6.2944	4.6311	0.7528	0.97564	7.0472
{'fl_cov_v'}	}	0.89089	1	0.9945	0.84708	0.91033
{'fl_cov_c'}	}	1.019	0.7528	0.12373	0.15568	1.1427
{'fl_cov_c'}	}	0.88234	0.9945	1	0.82696	0.90306
{'fl_cov_y'}	}	1.0643	0.97564	0.15568	0.28645	1.2199
{'fl_cov_y'}	}	0.60566	0.84708	0.82696	1	0.63363
{'fl_cov_coh'}	}	11.798	7.0472	1.1427	1.2199	12.941
{'fl_cov_coh'}	}	0.99894	0.91033	0.90306	0.63363	1
{'fl_cov_savefraccoh'}		0.64446	0.46366	0.077608	0.077311	0.72207
{'fl_cov_savefraccoh'}		0.78015	0.85631	0.8769	0.57411	0.79776
{'fracByP0_01'}	}	0	7.366e-06	9.1288e-05	2.5324e-05	2.9613e-05
{'fracByP0_1'}	}	0	0.00015226	0.00040756	0.00048297	0.00013202
{'fracByP1'}	}	0	0.0031657	0.0040997	0.0058265	0.0013172
{'fracByP5'}	}	0	0.020854	0.026015	0.023308	0.010613
{'fracByP10'}		0.0007829	0.049187	0.059665	0.051833	0.020313
{'fracByP20'}		0.010458	0.1169	0.13673	0.11782	0.052147
{'fracByP25'}		0.020375	0.15489	0.17838	0.15407	0.072616
{'fracByP30'}		0.033945	0.19501	0.22212	0.1924	0.09561
{'fracByP40'}		0.076084	0.28102	0.3131	0.2752	0.15182
{'fracByP50'}		0.13323	0.3766	0.41016	0.36618	0.22332
{'fracByP60'}		0.21876	0.4783	0.51311	0.46472	0.31143
{'fracByP70'}		0.32789	0.58936	0.62182	0.57246	0.4201
{'fracByP75'}		0.39329	0.64823	0.67676	0.63063	0.48449
{'fracByP80'}		0.47094	0.70976	0.73532	0.69204	0.55555
{'fracByP90'}		0.66575	0.84269	0.85851	0.82742	0.72907
{'fracByP95'}		0.8001	0.91584	0.92543	0.90488	0.84038
{'fracByP99'}		0.94734	0.98115	0.98337	0.97713	0.95746
{'fracByP99_9'}		0.99324	0.99789	0.99809	0.99717	0.99445
{'fracByP99_99'}		0.99909	0.99977	0.99979	0.99967	0.99931

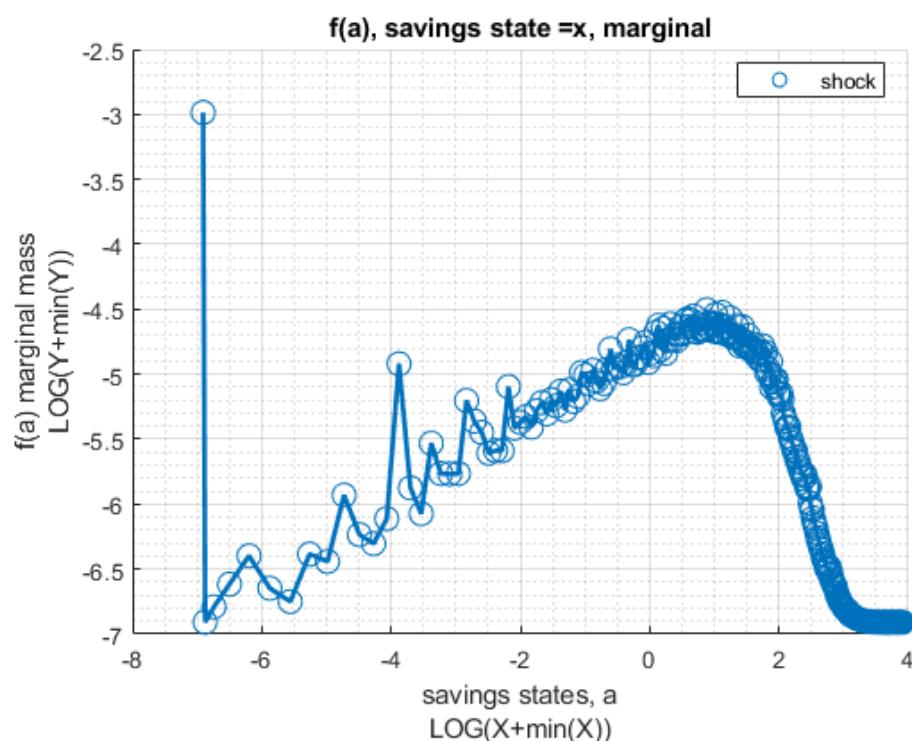
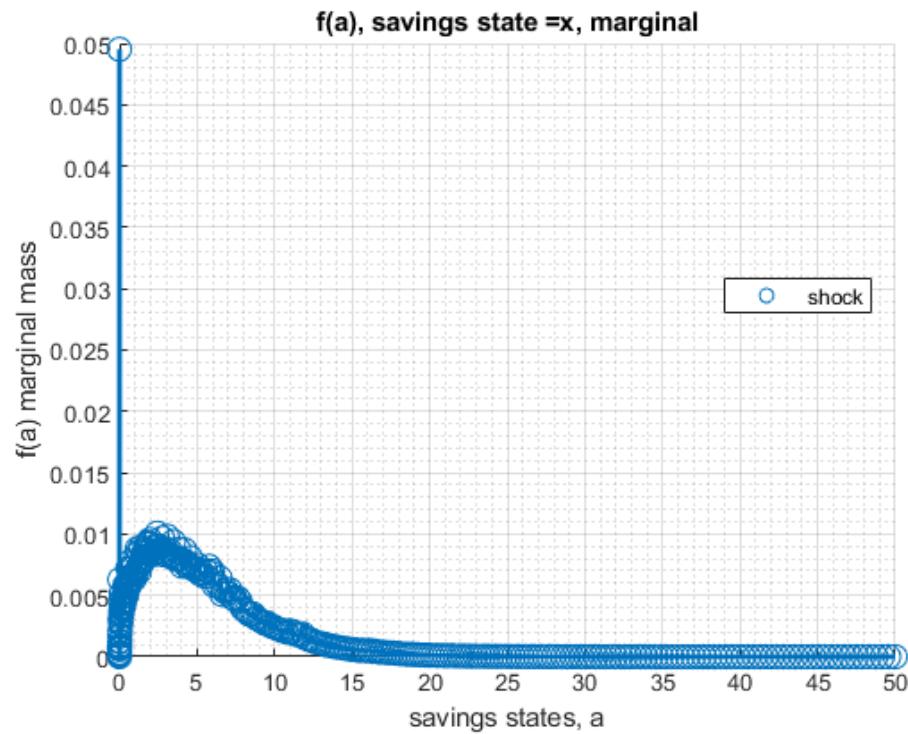
2.1.5 Test FF_DS_AZ_LOOP A grid 300 Shock Grid 50

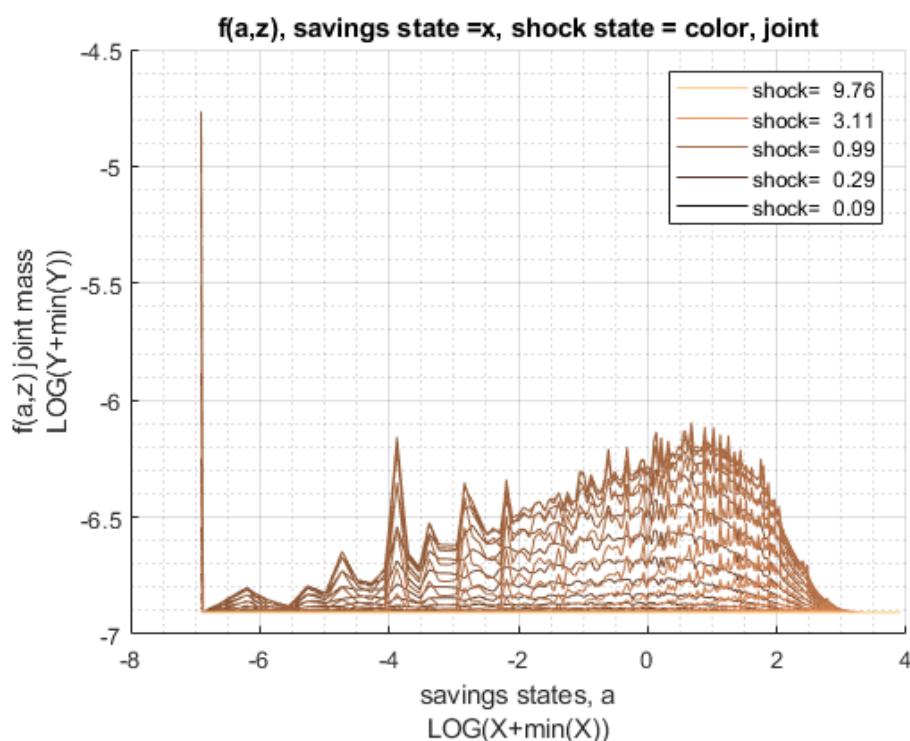
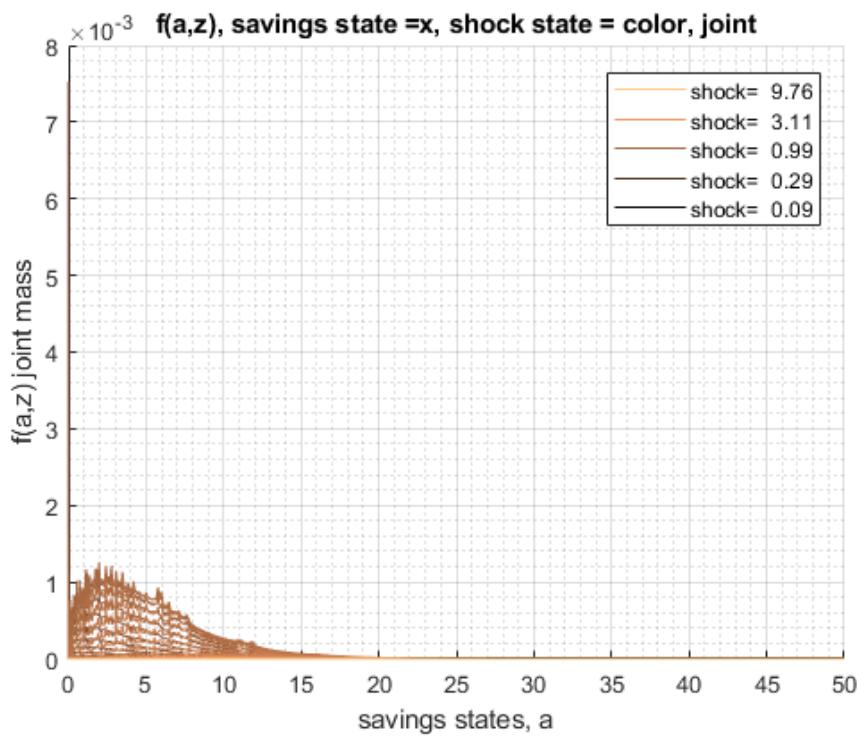
```

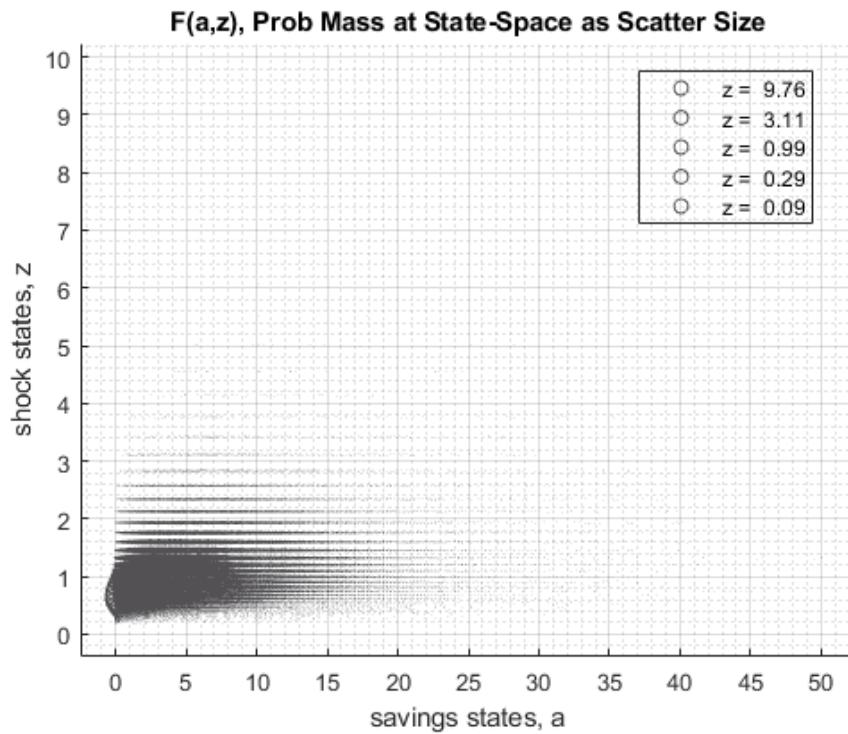
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_timer') = true;
mp_support('ls_ffcmd') = {};
mp_support('ls_ddcmd') = {};
mp_support('ls_ddgrh') = {'faz','fa'};
mp_support('bl_show_stats_table') = true;
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 300;
mp_params('it_z_n') = 50;
ff_ds_az_loop(mp_params, mp_support);

```

Elapsed time is 4.319877 seconds.
FF_DS_AZ_LOOP finished. Distribution took = 3.0884







xxx tb_outcomes: all stats xxx

OriginalVariableNames	ap	v	c	y	coh
{'mean'}	3.26	6.9484	1.5319	1.5305	4.7919
{'sd'}	3.3166	2.1606	0.35167	0.5364	3.6315
{'coefofvar'}	1.0174	0.31094	0.22956	0.35048	0.75783
{'min'}	0	-7.6871	0.12843	0.12843	0.12843
{'max'}	50	20.751	15.657	15.657	65.657
{'pYiso'}	0.049546	0	0	0	0
{'pYls0'}	0	0.00011924	0	0	0
{'pYgr0'}	0.95045	0.99988	1	1	1
{'pYisMINY'}	0.049546	1.1021e-15	1.1021e-15	1.1021e-15	1.1021e-15
{'pYisMAXY'}	5.1436e-09	3.0978e-19	3.0978e-19	3.0978e-19	3.0978e-19
{'p0_01'}	0	-0.20486	0.40271	0.40271	0.40271
{'p0_1'}	0	1.2135	0.53589	0.488	0.53589
{'p1'}	0	2.3687	0.71312	0.64833	0.71312
{'p5'}	0.000050419	3.5428	0.94895	0.8071	0.96945
{'p10'}	0.11149	4.2401	1.0944	0.93681	1.2484
{'p20'}	0.51629	5.0791	1.255	1.072	1.7729
{'p25'}	0.75904	5.4237	1.3033	1.1504	2.067
{'p30'}	1.0189	5.7339	1.3518	1.2006	2.3841
{'p40'}	1.6286	6.2919	1.446	1.3198	3.0593
{'p50'}	2.2834	6.8389	1.5355	1.4423	3.8053
{'p60'}	3.0751	7.4137	1.613	1.5765	4.7113
{'p70'}	4.1046	8.0318	1.7011	1.7318	5.8286
{'p75'}	4.7891	8.3723	1.7435	1.8266	6.5055
{'p80'}	5.5379	8.765	1.8035	1.9295	7.3201
{'p90'}	7.6355	9.7879	1.9921	2.2457	9.6214
{'p95'}	9.8311	10.68	2.1096	2.5308	11.976
{'p99'}	14.653	12.305	2.407	3.1554	17.087
{'p99_9'}	21.166	14.067	2.7771	4.0255	23.953
{'p99_99'}	27.382	15.467	3.1325	4.887	30.554
{'fl_cov_ap'}	11	6.3988	1.032	1.0771	12.032

{'fl_cor_ap'}	}	1	0.89298	0.88481	0.60546	0.99898
{'fl_cov_v'}	}	6.3988	4.668	0.75538	0.97839	7.1542
{'fl_cov_v'}	}	0.89298	1	0.99418	0.84423	0.91183
{'fl_cov_c'}	}	1.032	0.75538	0.12367	0.15613	1.1557
{'fl_cov_c'}	}	0.88481	0.99418	1	0.82768	0.90493
{'fl_cov_y'}	}	1.0771	0.97839	0.15613	0.28772	1.2333
{'fl_cov_y'}	}	0.60546	0.84423	0.82768	1	0.63312
{'fl_cov_coh'}	}	12.032	7.1542	1.1557	1.2333	13.188
{'fl_cov_coh'}	}	0.99898	0.91183	0.90493	0.63312	1
{'fl_cov_savefraccoh'}	}	0.65387	0.46619	0.077331	0.076912	0.7312
{'fl_cov_savefraccoh'}	}	0.78182	0.85567	0.87203	0.56861	0.79848
{'fracByP0_01'}	}	0	-7.082e-06	2.6291e-05	3.0744e-05	8.4044e-06
{'fracByP0_1'}	}	0	8.1705e-05	0.00058298	0.00029929	0.00018591
{'fracByP1'}	}	0	0.0025872	0.0055744	0.0043199	0.0017463
{'fracByP5'}	}	5.9482e-08	0.02063	0.028475	0.023256	0.0085179
{'fracByP10'}	}	0.00083251	0.049013	0.059787	0.051875	0.020182
{'fracByP20'}	}	0.01069	0.11692	0.13707	0.11785	0.051473
{'fracByP25'}	}	0.021006	0.15459	0.17869	0.15432	0.071586
{'fracByP30'}	}	0.034297	0.19493	0.22235	0.19226	0.095063
{'fracByP40'}	}	0.076942	0.2811	0.31433	0.27537	0.15173
{'fracByP50'}	}	0.13547	0.37553	0.41049	0.36597	0.22294
{'fracByP60'}	}	0.21688	0.47822	0.51321	0.46464	0.31179
{'fracByP70'}	}	0.32617	0.58918	0.6213	0.57279	0.42106
{'fracByP75'}	}	0.40001	0.64825	0.67795	0.6311	0.48455
{'fracByP80'}	}	0.47816	0.71036	0.73507	0.69272	0.55654
{'fracByP90'}	}	0.67319	0.84299	0.85862	0.82739	0.73089
{'fracByP95'}	}	0.80347	0.91616	0.92515	0.90483	0.84244
{'fracByP99'}	}	0.94675	0.98117	0.98325	0.97691	0.95831
{'fracByP99_9'}	}	0.99284	0.99789	0.9981	0.99713	0.99445
{'fracByP99_99'}	}	0.99909	0.99977	0.99979	0.99966	0.9993

2.2 FF_DS_AZ_CTS_LOOP Dynamic Savings Loop Continuous Distribution

Go back to fan's MEconTools Toolbox ([bookdown](#)), Matlab Code Examples Repository ([bookdown](#)), or Math for Econ with Matlab Repository ([bookdown](#)).

This is the example vignette for function: [ff_ds_az_cts_loop](#) from the [MEconTools Package](#). F(a,z) discrete probability mass function given policy function solution with continuous savings choices.

- Distribution for Common Choice and States Grid : [ff_ds_az_cts_loop](#)
- Distribution for States Grid + Continuous Exact Savings as Share of Cash-on-Hand : [ff_ds_az_cts_loop](#)

2.2.1 Test FF_DS_AZ_CTS_LOOP Defaults

Call the function with defaults. By default, shows the asset policy function summary. Model parameters can be changed by the mp_params.

```
%mp_params
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('fl_crqa') = 1.5;
mp_params('fl_beta') = 0.94;
% call function
ff_ds_az_cts_loop(mp_params);
```

Elapsed time is 1.029654 seconds.

xx

CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefvari	min
	-	---	----	-----	-----	-----	-----	-----	-----	-----	-----
ap	1	1	2	700	100	7	9863.4	14.091	14.388	1.0211	0

xxx TABLE:ap xxxxxxxxxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6	c7
	-----	-----	-----	-----	-----	-----	-----
r1	0	0	0	0.053491	0.25574	0.60604	1.1157
r2	0	0	0	0.053998	0.25571	0.6066	1.1163
r3	0	0	0	0.056449	0.25576	0.60907	1.1187
r4	0	0	0	0.061799	0.26016	0.6109	1.1239
r5	0	0	0	0.066463	0.26897	0.61141	1.1327
r96	43.388	43.52	43.701	43.925	44.222	44.68	45.228
r97	44.566	44.695	44.878	45.103	45.398	45.856	46.403
r98	45.761	45.892	46.072	46.298	46.592	47.05	47.597
r99	46.973	47.107	47.286	47.514	47.806	48.263	48.815
r100	48.206	48.338	48.519	48.746	49.037	49.497	50.117

FF_DS_AZ_CTS_LOOP finished. Distribution took = 0.25795

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

CONTAINER NAME: mp_ddcmd ND Array (Matrix etc)

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefvari
	-	---	----	-----	-----	-----	---	-----	-----	-----
fa	1	1	2	100	100	1	1	0.01	0.0155	1.55
faz	2	2	2	700	100	7	1	0.0014286	0.003424	2.3968
fz	3	3	2	7	7	1	1	0.14286	0.11742	0.82196

xxx TABLE:fa xxxxxxxxxxxxxxxxx

	c1

r1	0.11839
r2	0.00028039
r3	2.8585e-05
r4	0.0082178
r5	0.0062146
r96	1.3607e-18
r97	2.0727e-19
r98	2.7005e-20
r99	2.9248e-21
r100	2.6966e-22

xxx TABLE:faz xxxxxxxxxxxxxxxxx

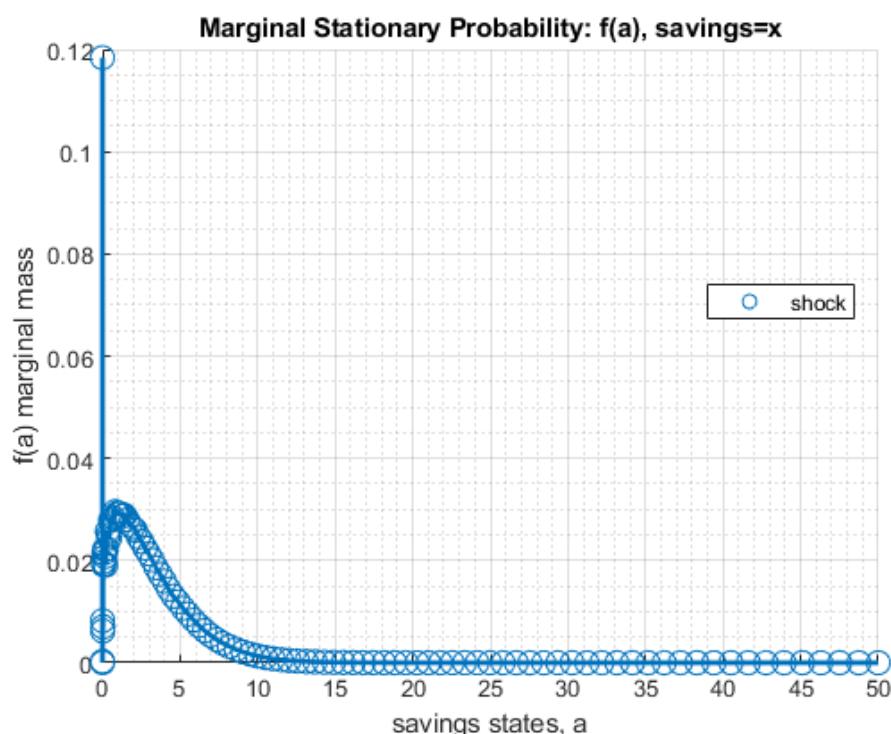
	c1	c2	c3	c4	c5	c6
	-----	-----	-----	-----	-----	-----
r1	0.0082492	0.036999	0.05152	0.018557	0.0028578	0.00020313
r2	0.00014901	9.934e-05	2.7594e-05	4.088e-06	3.4067e-07	1.5141e-08
r3	1.0791e-06	3.8554e-06	1.588e-05	6.6114e-06	1.0779e-06	7.8977e-08
r4	0.00016483	0.0019292	0.004208	0.0016366	0.00025991	1.8779e-05

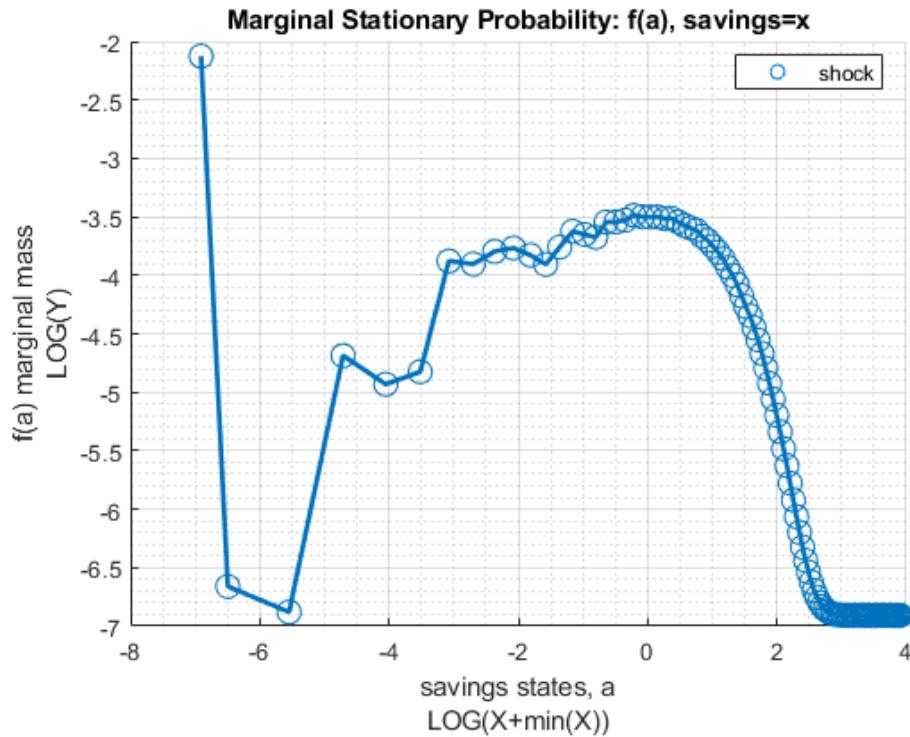
r5	0.00019509	0.00082304	0.0034877	0.0014538	0.00023711	1.7374e-05	4.7
r96	4.1576e-23	1.0459e-21	1.1798e-20	7.4995e-20	2.7503e-19	5.3901e-19	4.58
r97	5.3415e-24	1.4108e-22	1.6619e-21	1.0943e-20	4.1203e-20	8.2324e-20	7.09
r98	5.734e-25	1.6065e-23	1.9875e-22	1.3596e-21	5.2668e-21	1.075e-20	9.4
r99	4.7136e-26	1.4644e-24	1.9531e-23	1.4042e-22	5.6108e-22	1.1675e-21	1.03
r100	1.9078e-27	7.8348e-26	1.2906e-24	1.0816e-23	4.8188e-23	1.0831e-22	1.00

xxx TABLE:fz xxxxxxxxxxxxxxxxx

c1

r1	0.015625
r2	0.09375
r3	0.23438
r4	0.3125
r5	0.23438
r6	0.09375
r7	0.015625





xxx tb_outcomes: all stats xxx

OriginalVariableNames	ap	v	c	y	coh
{'mean'}	1.6576	5.0855	1.4665	1.4663	3.1241
{'sd'}	1.9603	1.7128	0.362	0.51116	2.2726
{'coefofvar'}	1.1826	0.33679	0.24684	0.3486	0.72744
{'min'}	0	0.87463	0.58543	0.58543	0.58543
{'max'}	50.117	16.344	4.8795	4.9969	54.997
{'pYiso'}	0.1184	0	0	0	0
{'pYls0'}	0	0	0	0	0
{'pYgr0'}	0.8816	1	1	1	1
{'pYisMINY'}	0.1184	0.0082492	0.0082492	0.0082492	0.0082492
{'pYisMAXY'}	1.0098e-22	1.0098e-22	1.0098e-22	1.0098e-22	1.0098e-22
{'p0_01'}	0	0.87463	0.58543	0.58543	0.58543
{'p0_1'}	0	0.87463	0.58543	0.58543	0.58543
{'p1'}	0	1.1243	0.69861	0.59041	0.715
{'p5'}	0	2.0791	0.77687	0.76855	0.78562
{'p10'}	0	3.1895	1.009	0.85364	1.009
{'p20'}	0.1057	3.4752	1.14	1.0154	1.3246
{'p25'}	0.1939	3.8676	1.2593	1.0372	1.4541
{'p30'}	0.31246	4.2445	1.288	1.0797	1.5906
{'p40'}	0.60724	4.5309	1.3707	1.3296	1.9628
{'p50'}	0.95427	5.055	1.4829	1.3613	2.4022
{'p60'}	1.4469	5.5086	1.5637	1.4343	2.9909
{'p70'}	2.0596	5.9381	1.6462	1.7599	3.7395
{'p75'}	2.4165	6.2179	1.7114	1.7855	4.1539
{'p80'}	2.8138	6.5733	1.7777	1.824	4.6604
{'p90'}	4.2696	7.3417	1.9216	2.311	6.1793
{'p95'}	5.8173	8.0019	2.0504	2.4211	7.7898
{'p99'}	8.6172	9.1635	2.3145	3.1157	10.795
{'p99_9'}	12.332	10.32	2.5888	3.3595	14.819
{'p99_99'}	15.614	11.187	2.8357	3.5223	18.494
{'fl_cov_ap'}	3.8427	2.8209	0.59546	0.62646	4.4381

{'fl_cor_ap'}	}	1	0.84018	0.83914	0.6252	0.99624
{'fl_cov_v'}	}	2.8209	2.9336	0.61788	0.78698	3.4388
{'fl_cov_v'}	}	0.84018	1	0.99656	0.8989	0.88346
{'fl_cov_c'}	}	0.59546	0.61788	0.13104	0.16288	0.7265
{'fl_cov_c'}	}	0.83914	0.99656	1	0.88023	0.88311
{'fl_cov_y'}	}	0.62646	0.78698	0.16288	0.26129	0.78934
{'fl_cov_y'}	}	0.6252	0.8989	0.88023	1	0.67949
{'fl_cov_coh'}	}	4.4381	3.4388	0.7265	0.78934	5.1646
{'fl_cov_coh'}	}	0.99624	0.88346	0.88311	0.67949	1
{'fl_cov_savefraccoh'}	}	0.41171	0.36784	0.079955	0.080066	0.49166
{'fl_cov_savefraccoh'}	}	0.84353	0.86257	0.88709	0.62909	0.86891
{'fracByP0_01'}	}	0	0.0014187	0.003293	0.0032935	0.0015458
{'fracByP0_1'}	}	0	0.0014187	0.003293	0.0032935	0.0015458
{'fracByP1'}	}	0	0.0018	0.0041476	0.0040773	0.0019486
{'fracByP5'}	}	0	0.017798	0.025084	0.025722	0.011837
{'fracByP10'}	}	0	0.069566	0.076643	0.051708	0.032927
{'fracByP20'}	}	0.0028528	0.1122	0.13024	0.1217	0.065169
{'fracByP25'}	}	0.0077609	0.14388	0.17442	0.15825	0.090199
{'fracByP30'}	}	0.016336	0.1847	0.21519	0.1908	0.11027
{'fracByP40'}	}	0.044743	0.27669	0.31043	0.27733	0.16769
{'fracByP50'}	}	0.091661	0.37143	0.40445	0.37462	0.2384
{'fracByP60'}	}	0.1676	0.47128	0.50501	0.46524	0.33103
{'fracByP70'}	}	0.27323	0.58248	0.6172	0.57522	0.43968
{'fracByP75'}	}	0.33601	0.64052	0.67429	0.63346	0.50276
{'fracByP80'}	}	0.41177	0.70413	0.73317	0.69614	0.57118
{'fracByP90'}	}	0.62757	0.84178	0.85697	0.82738	0.73915
{'fracByP95'}	}	0.77414	0.9151	0.92509	0.91117	0.84868
{'fracByP99'}	}	0.9381	0.98132	0.98368	0.97823	0.9596
{'fracByP99_9'}	}	0.99212	0.99801	0.99826	0.99811	0.99474
{'fracByP99_99'}	}	0.99909	0.9998	0.99982	0.99981	0.99944

2.2.2 Test FF_DS_AZ_CTS_LOOP Speed Tests

Call the function with different a and z grid size, print out speed:

```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_timer') = true;
mp_support('ls_ffcmd') = {};
mp_support('ls_ddcmd') = {};
mp_support('ls_ddgrh') = {};
mp_support('bl_show_stats_table') = false;
% A grid 50, shock grid 5:
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 50;
mp_params('it_z_n') = 5;
ff_ds_az_cts_loop(mp_params, mp_support);
```

Elapsed time is 0.610510 seconds.
FF_DS_AZ_CTS_LOOP finished. Distribution took = 0.081975

```
% A grid 100, shock grid 7:
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 100;
mp_params('it_z_n') = 7;
ff_ds_az_cts_loop(mp_params, mp_support);
```

Elapsed time is 1.114978 seconds.
FF_DS_AZ_CTS_LOOP finished. Distribution took = 0.18449

```
% A grid 200, shock grid 9:
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 200;
mp_params('it_z_n') = 9;
ff_ds_az_cts_loop(mp_params, mp_support);

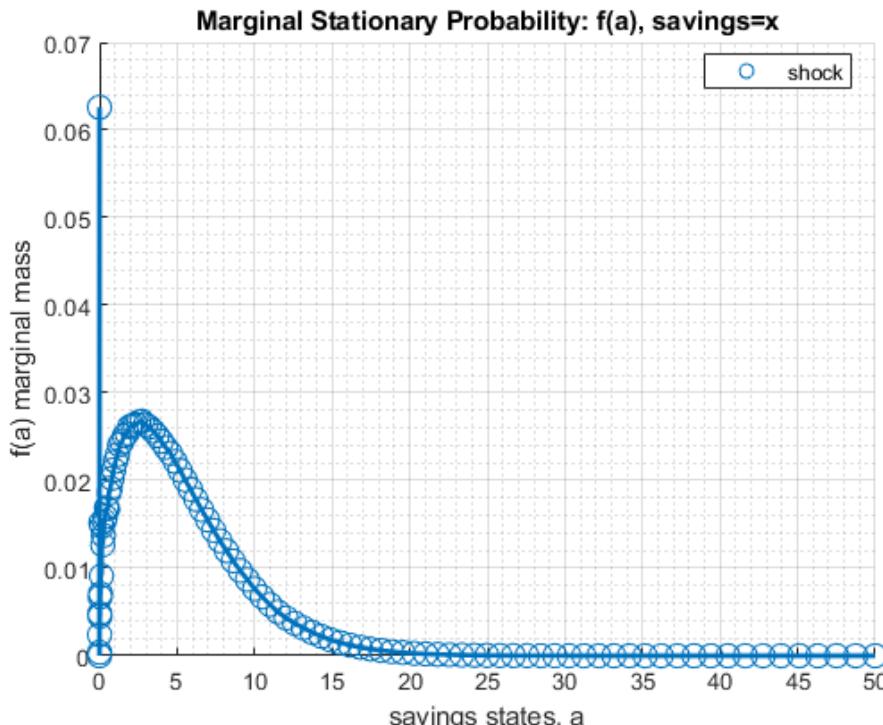
Elapsed time is 2.014970 seconds.
FF_DS_AZ_CTS_LOOP finished. Distribution took = 0.62806
```

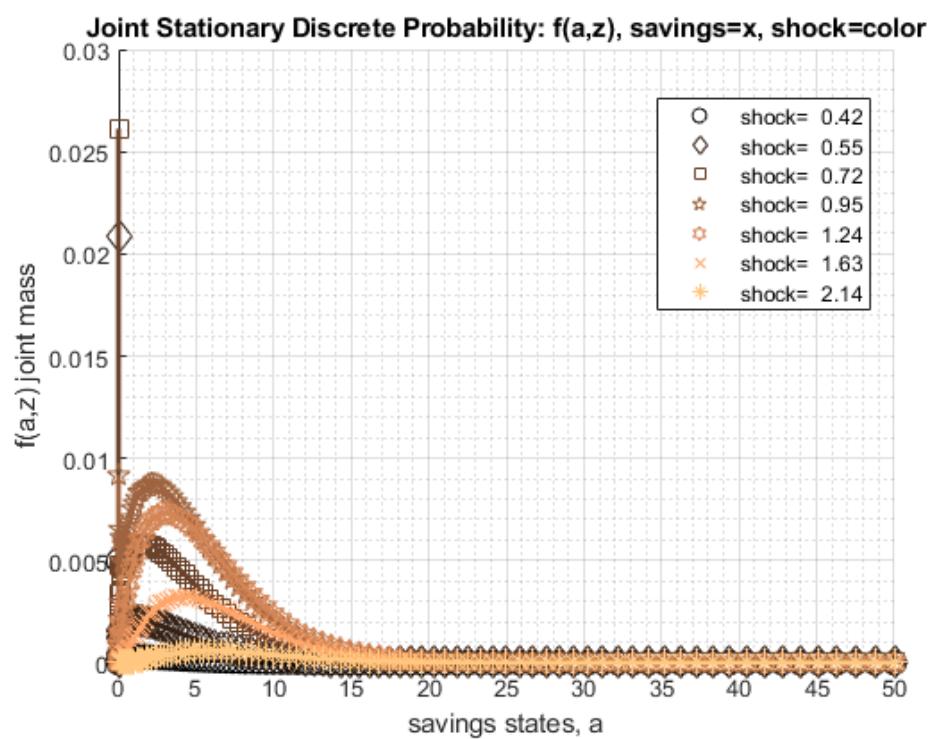
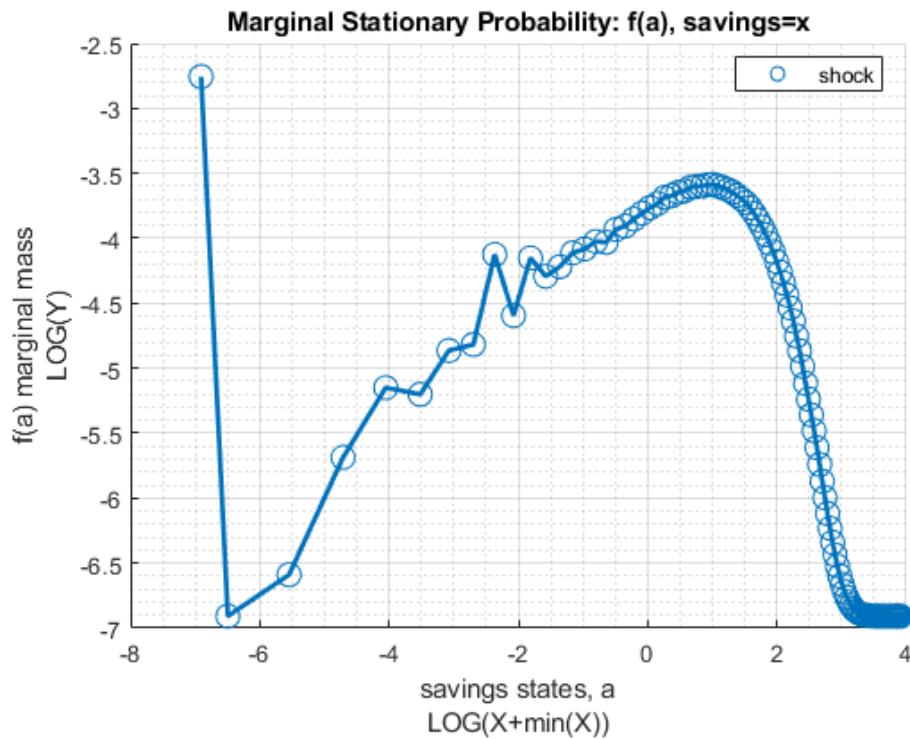
2.2.3 Test FF_DS_AZ_CTS_LOOP A grid 100 Shock grid 7

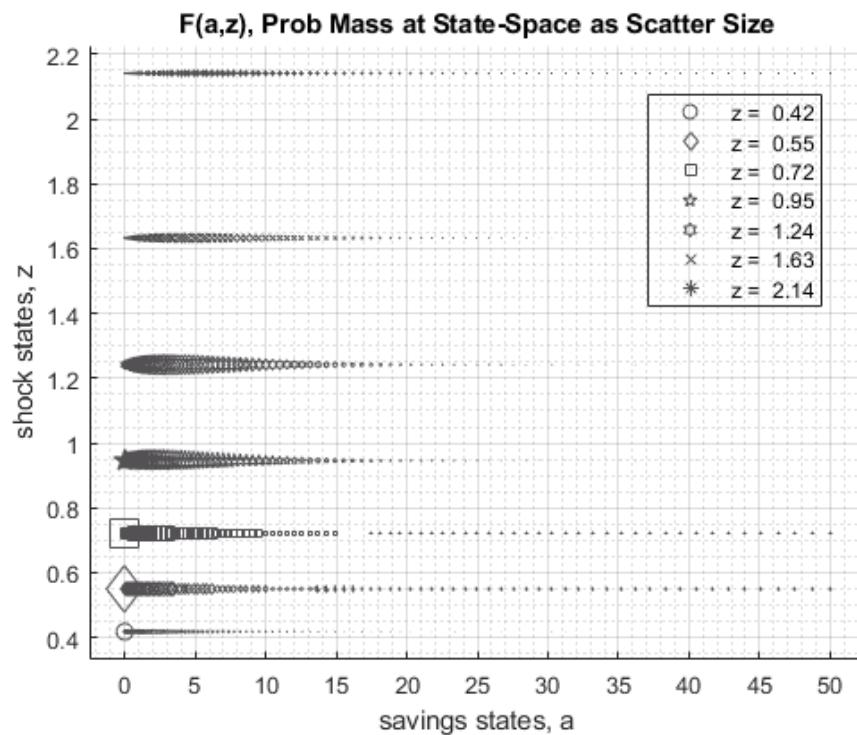
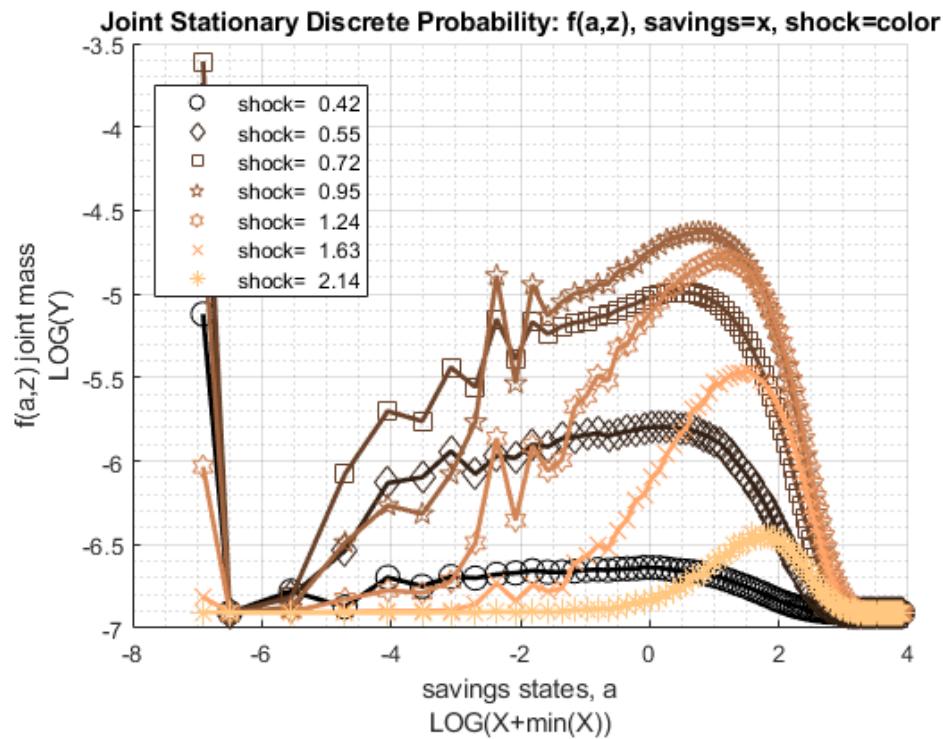
Call the function with different a and z grid size, print out speed:

```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_timer') = true;
mp_support('ls_ffcmd') = {};
mp_support('ls_ddcmd') = {};
mp_support('ls_ddgrh') = {'faz','fa'};
mp_support('bl_show_stats_table') = true;
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 100;
mp_params('it_z_n') = 7;
ff_ds_az_cts_loop(mp_params, mp_support);

Elapsed time is 0.953345 seconds.
FF_DS_AZ_CTS_LOOP finished. Distribution took = 0.23426
```







xxx tb_outcomes: all stats xxx

OriginalVariableNames	ap	v	c	y	coh
{'mean'}	3.2216	6.9329	1.5295	1.5289	4.7511
{'sd'}	3.2562	2.1508	0.34914	0.5307	3.5687
{'coefofvar'}	1.0107	0.31024	0.22827	0.34711	0.75113
{'min'}	0	1.7008	0.58543	0.58543	0.58543
{'max'}	50.789	19.213	4.21	4.9969	54.997
{'pYiso'}	0.062608	0	0	0	0

{'pYls0'	}	0	0	0	0	0
{'pYgr0'	}	0.93739	1	1	1	1
{'pYisMINY'	}	0.062608	0.0049772	0.0049772	0.0049772	0.0049772
{'pYisMAXY'	}	2.9501e-11	2.9501e-11	3.1223e-11	2.9501e-11	2.9501e-11
{'p0_01'	}	0	1.7008	0.58543	0.58543	0.58543
{'p0_1'	}	0	1.7008	0.58543	0.58543	0.58543
{'p1'	}	0	2.9492	0.76855	0.62688	0.76855
{'p5'	}	0	3.4945	0.97884	0.78105	1.009
{'p10'	}	0.092835	4.1716	1.0603	0.97609	1.223
{'p20'	}	0.47609	5.1938	1.2588	1.0456	1.7419
{'p25'	}	0.7311	5.3812	1.3008	1.094	2.0576
{'p30'	}	0.97803	5.6276	1.351	1.188	2.3618
{'p40'	}	1.5512	6.3139	1.4528	1.349	3.0158
{'p50'	}	2.233	6.8328	1.5245	1.4175	3.7588
{'p60'	}	3.0801	7.416	1.6192	1.5453	4.6604
{'p70'	}	4.105	8.0461	1.7025	1.7909	5.7649
{'p75'	}	4.6992	8.4292	1.7544	1.84	6.4292
{'p80'	}	5.4329	8.7432	1.8159	1.9097	7.3478
{'p90'	}	7.7004	9.7559	1.9663	2.3407	9.5263
{'p95'	}	9.7011	10.662	2.1066	2.5036	11.722
{'p99'	}	14.279	12.148	2.3613	3.1795	16.608
{'p99_9'	}	19.899	13.734	2.6792	3.5223	22.615
{'p99_99'	}	25.265	14.885	2.9563	3.7789	28.175
{'fl_cov_ap'	}	10.603	6.2617	1.0053	1.0453	11.608
{'fl_cor_ap'	}	1	0.89408	0.8843	0.60489	0.99896
{'fl_cov_v'	}	6.2617	4.626	0.74802	0.96794	7.0097
{'fl_cor_v'	}	0.89408	1	0.99613	0.848	0.91325
{'fl_cov_c'	}	1.0053	0.74802	0.1219	0.15425	1.1272
{'fl_cor_c'	}	0.8843	0.99613	1	0.83252	0.9047
{'fl_cov_y'	}	1.0453	0.96794	0.15425	0.28164	1.1995
{'fl_cor_y'	}	0.60489	0.848	0.83252	1	0.63337
{'fl_cov_coh'	}	11.608	7.0097	1.1272	1.1995	12.735
{'fl_cor_coh'	}	0.99896	0.91325	0.9047	0.63337	1
{'fl_cov_savefraccoh'}		0.65544	0.47179	0.078595	0.078136	0.73404
{'fl_cor_savefraccoh'}		0.78925	0.86007	0.88265	0.57729	0.8065
{'fracByP0_01'	}	0	0.001221	0.0019051	0.0019058	0.00061329
{'fracByP0_1'	}	0	0.001221	0.0019051	0.0019058	0.00061329
{'fracByP1'	}	0	0.011511	0.013437	0.0039104	0.0042425
{'fracByP5'	}	0	0.021279	0.026546	0.024488	0.012268
{'fracByP10'	}	0.0006892	0.05109	0.059758	0.051739	0.020676
{'fracByP20'	}	0.0099846	0.12278	0.1366	0.12131	0.052438
{'fracByP25'	}	0.019425	0.15429	0.17945	0.15485	0.072434
{'fracByP30'	}	0.032212	0.19399	0.22206	0.19029	0.094665
{'fracByP40'	}	0.0737	0.28144	0.31482	0.27941	0.15063
{'fracByP50'	}	0.1321	0.3768	0.41124	0.37234	0.22365
{'fracByP60'	}	0.21336	0.48025	0.51513	0.4642	0.31463
{'fracByP70'	}	0.3254	0.59015	0.62157	0.57794	0.42288
{'fracByP75'	}	0.39769	0.65462	0.67967	0.6363	0.48537
{'fracByP80'	}	0.47503	0.71232	0.73844	0.70062	0.56134
{'fracByP90'	}	0.67403	0.84445	0.86104	0.82867	0.73331
{'fracByP95'	}	0.80886	0.92029	0.92647	0.90776	0.84668
{'fracByP99'	}	0.95057	0.98162	0.98401	0.97831	0.96163
{'fracByP99_9'	}	0.99336	0.99797	0.99826	0.99778	0.99494
{'fracByP99_99'	}	0.99924	0.99979	0.99981	0.99977	0.9994

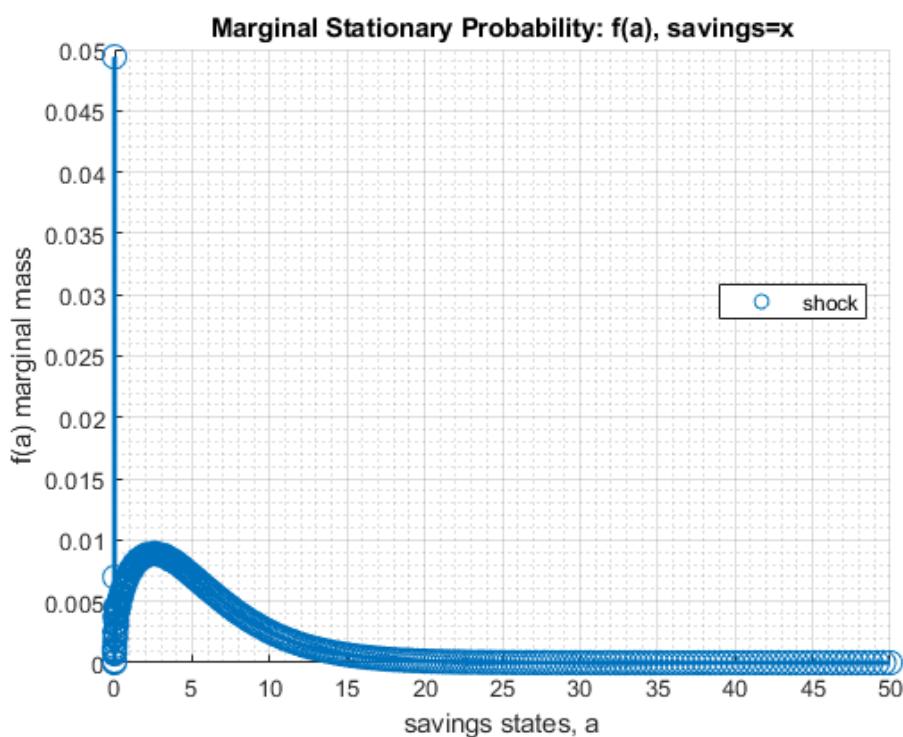
2.2.4 Test FF_DS_AZ_CTS_LOOP A grid 300 Shock grid 25

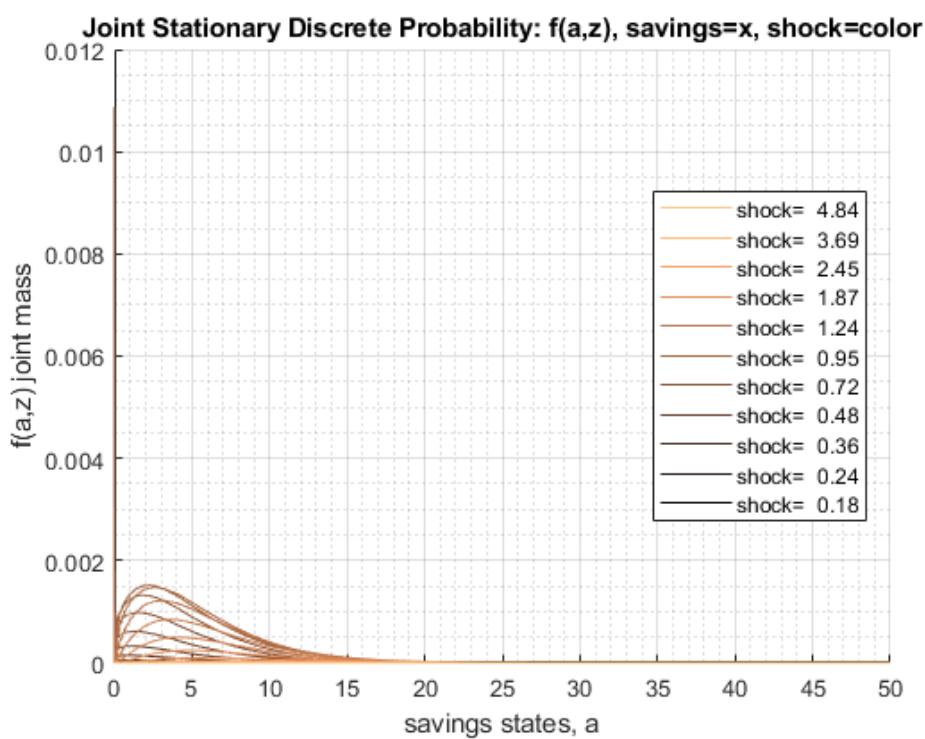
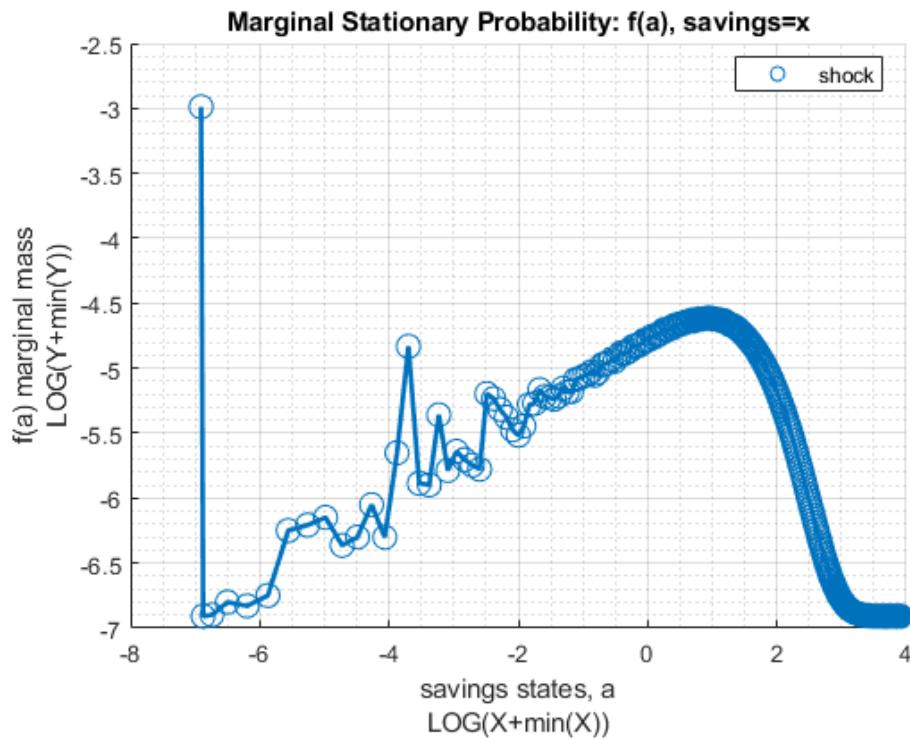
```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
```

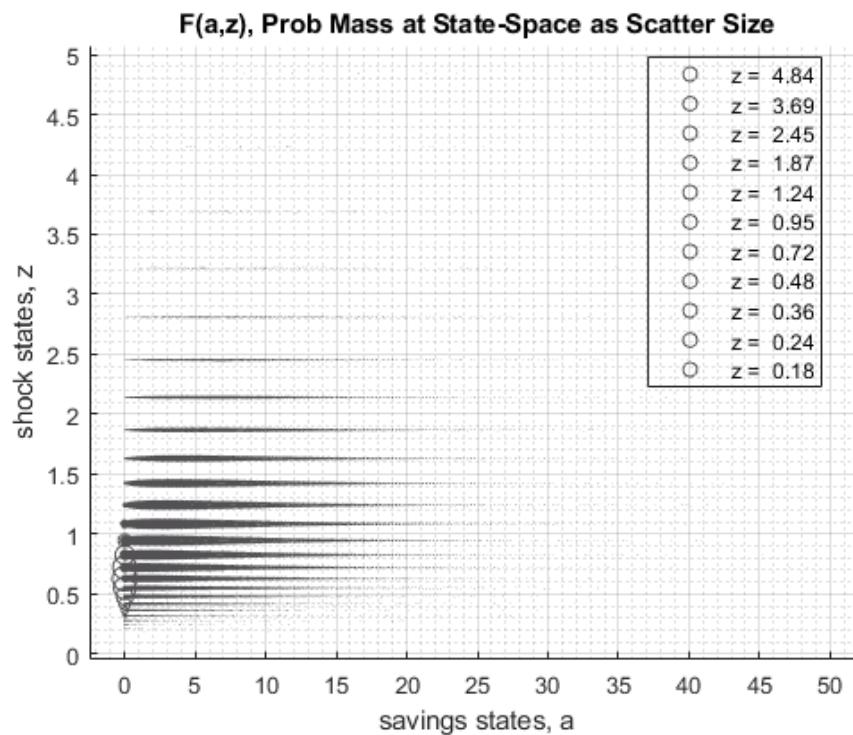
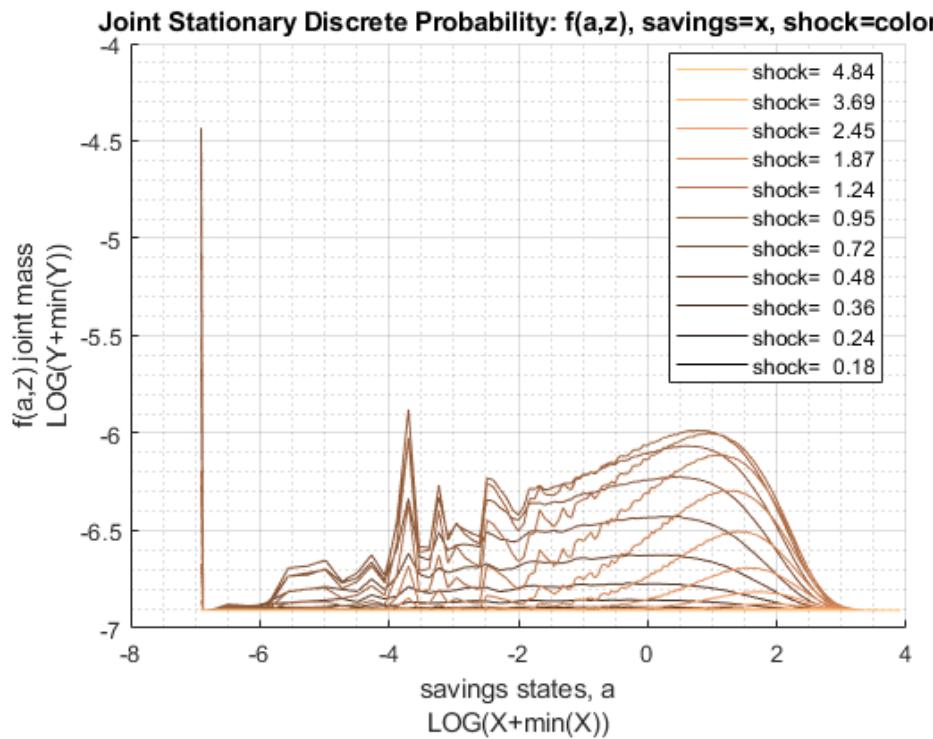
```
mp_support('bl_timer') = true;
mp_support('ls_ffcmd') = {};
mp_support('ls_ddcmd') = {};
mp_support('ls_ddgrh') = {'faz','fa'};
mp_support('bl_show_stats_table') = true;
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 300;
mp_params('it_z_n') = 25;
ff_ds_az_cts_loop(mp_params, mp_support);
```

Elapsed time is 11.056197 seconds.

FF_DS_AZ_CTS_LOOP finished. Distribution took = 2.3435







xxx tb_outcomes: all stats xxx

OriginalVariableNames	ap	v	c	y	coh
{'mean'}	3.2612	6.9497	1.5318	1.5305	4.793
{'sd'}	3.3352	2.1663	0.35078	0.5359	3.6495
{'coefofvar'}	1.0227	0.31171	0.229	0.35014	0.76143
{'min'}	0	-2.7616	0.25871	0.25871	0.25871
{'max'}	54.451	20.418	4.3301	8.7798	58.78
{'pYiso'}	0.04941	0	0	0	0

{'pYls0'}	}	0	7.3281e-05	0	0	0
{'pYgr0'}	}	0.95059	0.99993	1	1	1
{'pYisMINY'}	}	0.04941	3.1163e-08	3.1163e-08	3.1163e-08	3.1163e-08
{'pYisMAXY'}	}	2.8477e-13	2.8477e-13	1.121e-13	2.8477e-13	2.8477e-13
{'p0_01'}	}	0	0.33584	0.44588	0.42374	0.44588
{'p0_1'}	}	0	1.0287	0.51088	0.51088	0.51088
{'p1'}	}	0	2.33	0.67226	0.67069	0.67505
{'p5'}	}	0.0027154	3.5353	0.94151	0.8016	1.0088
{'p10'}	}	0.11496	4.1978	1.0921	0.9095	1.2356
{'p20'}	}	0.51133	5.096	1.2504	1.0657	1.779
{'p25'}	}	0.75298	5.4004	1.3077	1.1577	2.0685
{'p30'}	}	1.004	5.7312	1.3565	1.1951	2.3792
{'p40'}	}	1.5834	6.298	1.4458	1.3352	3.0372
{'p50'}	}	2.2686	6.8433	1.5287	1.441	3.7996
{'p60'}	}	3.0898	7.4098	1.6132	1.5764	4.6904
{'p70'}	}	4.0971	8.0297	1.7037	1.7526	5.7899
{'p75'}	}	4.7228	8.3787	1.7552	1.8223	6.462
{'p80'}	}	5.4827	8.7742	1.8144	1.9267	7.2769
{'p90'}	}	7.7718	9.8224	1.9746	2.2406	9.6945
{'p95'}	}	9.9683	10.704	2.1148	2.5163	12.048
{'p99'}	}	14.759	12.325	2.3956	3.157	17.176
{'p99_9'}	}	21.215	14.066	2.7525	3.9803	23.946
{'p99_99'}	}	27.205	15.415	3.0759	4.7968	30.277
{'fl_cov_ap'}	}	11.123	6.4528	1.0361	1.0808	12.16
{'fl_cor_ap'}	}	1	0.89313	0.88563	0.60472	0.999
{'fl_cov_v'}	}	6.4528	4.6928	0.75717	0.98035	7.21
{'fl_cor_v'}	}	0.89313	1	0.99643	0.84447	0.91198
{'fl_cov_c'}	}	1.0361	0.75717	0.12304	0.15594	1.1592
{'fl_cor_c'}	}	0.88563	0.99643	1	0.82954	0.90548
{'fl_cov_y'}	}	1.0808	0.98035	0.15594	0.28718	1.2368
{'fl_cor_y'}	}	0.60472	0.84447	0.82954	1	0.63237
{'fl_cov_coh'}	}	12.16	7.21	1.1592	1.2368	13.319
{'fl_cor_coh'}	}	0.999	0.91198	0.90548	0.63237	1
{'fl_cov_savefraccoh'}		0.65691	0.46786	0.07767	0.077234	0.73458
{'fl_cor_savefraccoh'}		0.78162	0.85705	0.87868	0.57192	0.79876
{'fracByP0_01'}	}	0	7.2341e-06	8.9677e-05	2.5415e-05	2.8657e-05
{'fracByP0_1'}	}	0	0.00014925	0.00040034	0.00047536	0.00012777
{'fracByP1'}	}	0	0.0031002	0.004056	0.0057421	0.0012982
{'fracByP5'}	}	4.4271e-07	0.020663	0.026101	0.023318	0.010275
{'fracByP10'}	}	0.00081444	0.049128	0.059669	0.051817	0.020124
{'fracByP20'}		0.010142	0.11647	0.13733	0.1174	0.051401
{'fracByP25'}		0.0197	0.15487	0.17845	0.15395	0.07176
{'fracByP30'}		0.033115	0.19474	0.22243	0.19298	0.095014
{'fracByP40'}		0.07268	0.28138	0.31442	0.27544	0.15079
{'fracByP50'}		0.13241	0.3756	0.41097	0.36527	0.22198
{'fracByP60'}		0.21444	0.47892	0.51282	0.46572	0.31091
{'fracByP70'}		0.323	0.58868	0.62139	0.57261	0.41949
{'fracByP75'}		0.39061	0.6478	0.67743	0.63129	0.48319
{'fracByP80'}		0.46952	0.70943	0.73587	0.6919	0.55532
{'fracByP90'}		0.66831	0.84297	0.85906	0.82754	0.72955
{'fracByP95'}		0.80219	0.91616	0.92541	0.90507	0.84194
{'fracByP99'}		0.94613	0.98125	0.98339	0.97711	0.95822
{'fracByP99_9'}		0.9927	0.9979	0.99812	0.99719	0.99443
{'fracByP99_99'}		0.99909	0.99977	0.99979	0.99967	0.99932

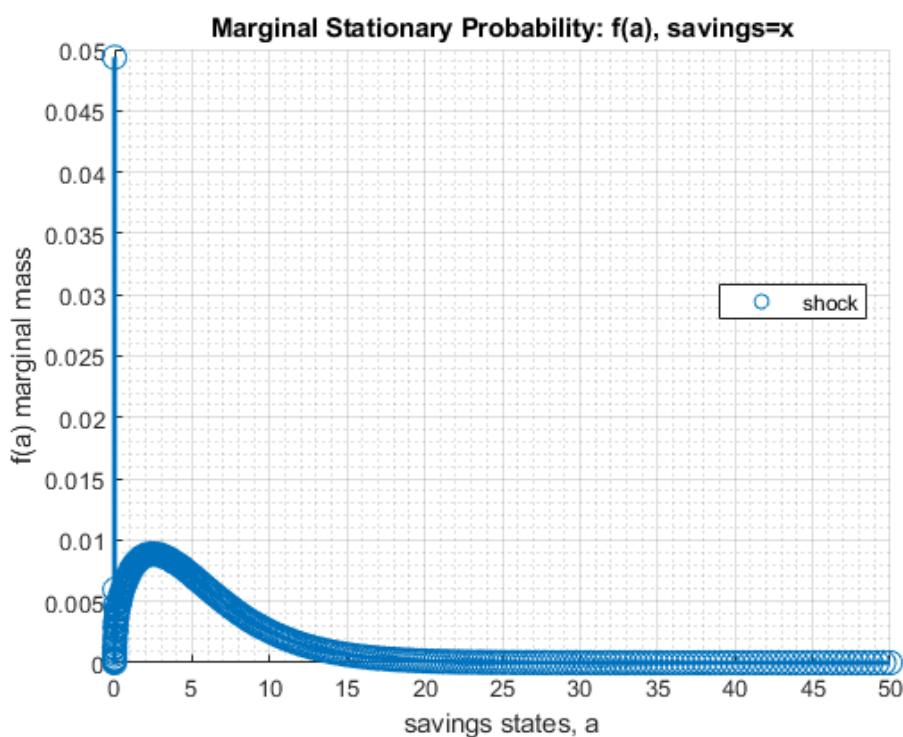
2.2.5 Test FF_DS_AZ_CTS_LOOP A grid 300 Shock grid 50

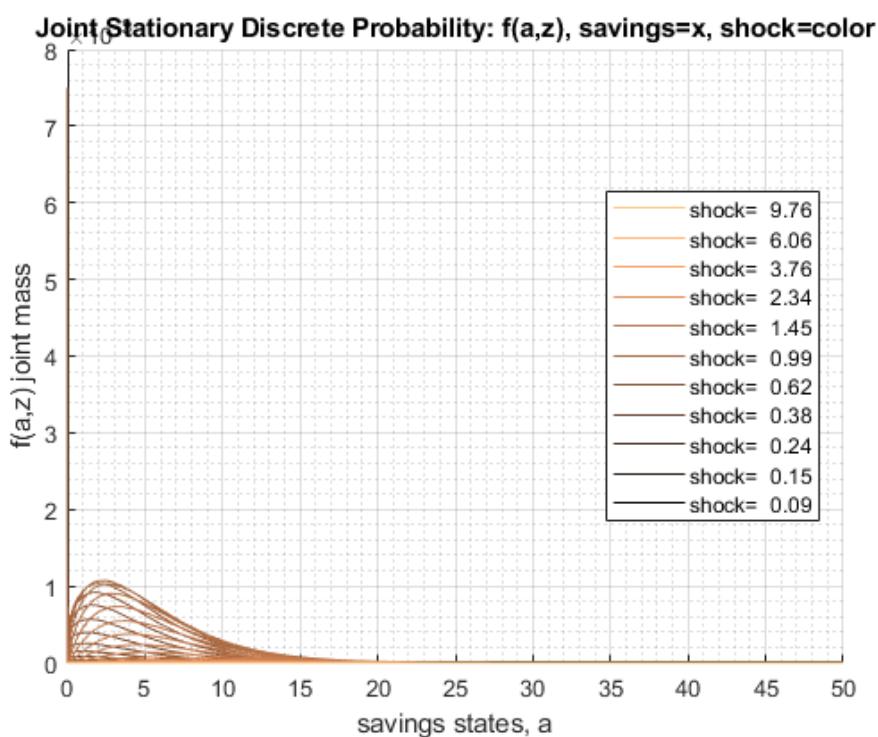
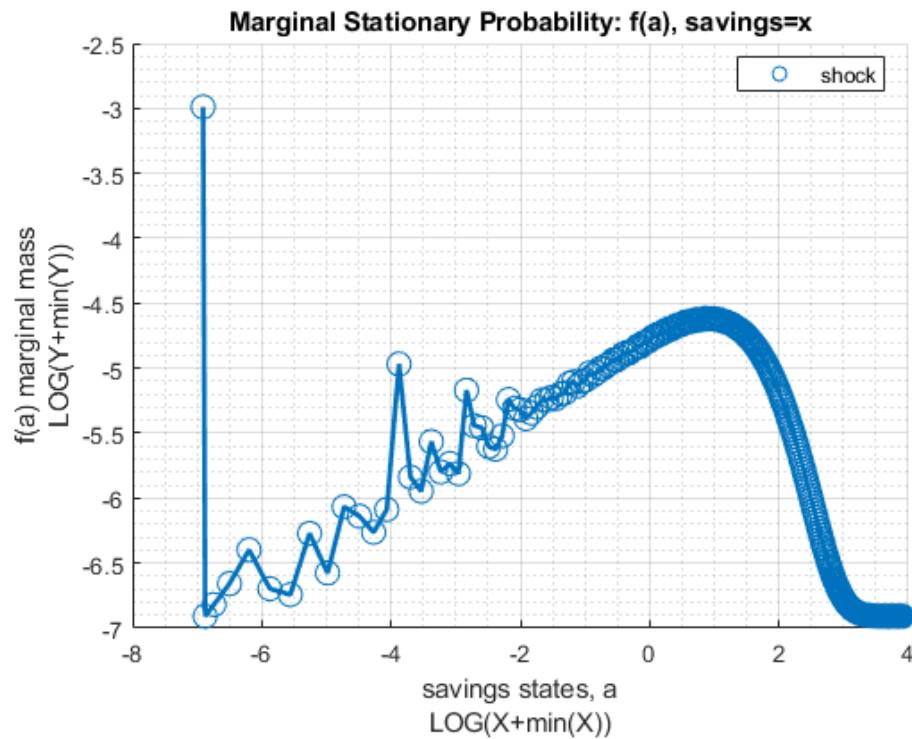
```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
```

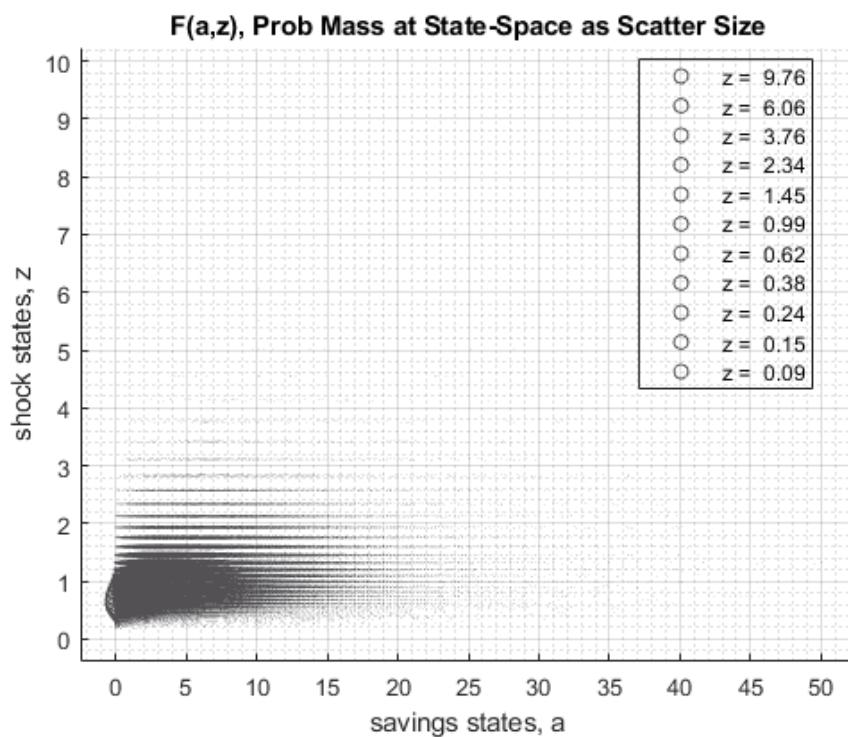
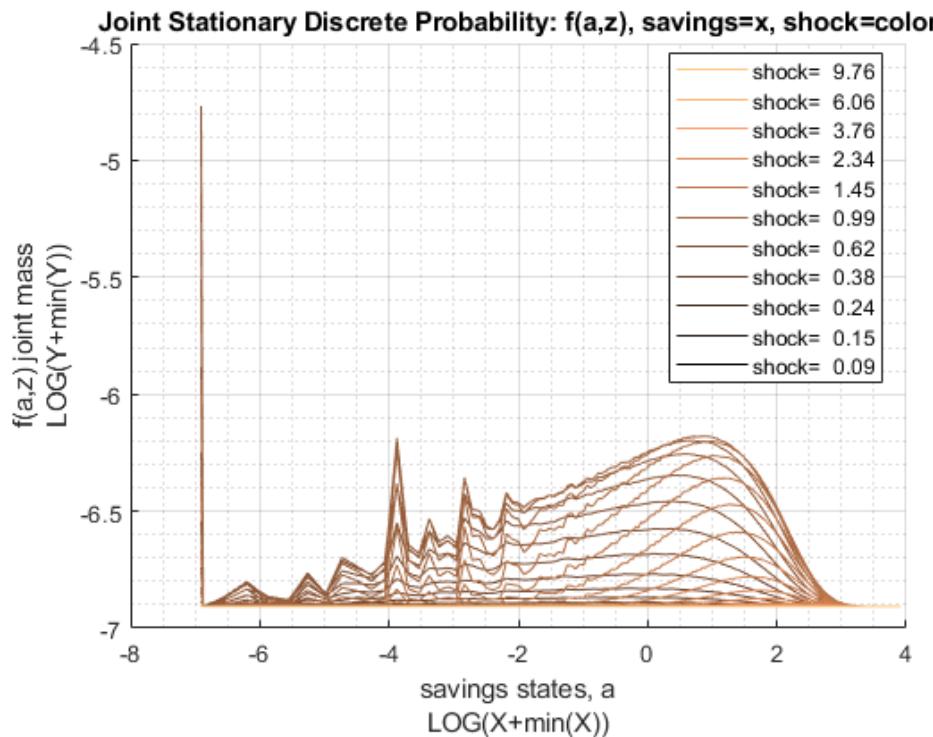
```
mp_support('bl_timer') = true;
mp_support('ls_ffcmd') = {};
mp_support('ls_ddcmd') = {};
mp_support('ls_ddgrh') = {'faz','fa'};
mp_support('bl_show_stats_table') = true;
mp_params = containers.Map('KeyType','char', 'ValueType','any');
mp_params('it_a_n') = 300;
mp_params('it_z_n') = 50;
ff_ds_az_cts_loop(mp_params, mp_support);
```

Elapsed time is 20.983438 seconds.

FF_DS_AZ_CTS_LOOP finished. Distribution took = 5.2169







xxx tb_outcomes: all stats xxx

OriginalVariableNames	ap	v	c	y	coh
{'mean'}	3.2794	6.957	1.5328	1.5312	4.8122
{'sd'}	3.3623	2.1722	0.35142	0.53693	3.6772
{'coefofvar'}	1.0253	0.31224	0.22927	0.35065	0.76415
{'min'}	0	-7.6866	0.12843	0.12843	0.12843
{'max'}	61.275	22.164	4.3849	15.657	65.657
{'pYiso'}	0.049376	0	0	0	0

{'pYls0'}	}	0	0.00011917	0	0	0
{'pYgr0'}	}	0.95062	0.99988	1	1	1
{'pYisMINY'}	}	0.049376	1.1048e-15	1.1048e-15	1.1048e-15	1.1048e-15
{'pYisMAXY'}	}	1.584e-18	1.584e-18	5.0847e-19	1.584e-18	1.584e-18
{'p0_01'}	}	0	-0.20427	0.40271	0.40271	0.40271
{'p0_1'}	}	0	1.2141	0.53589	0.48816	0.53589
{'p1'}	}	0	2.3693	0.71312	0.64833	0.71312
{'p5'}	}	0.001023	3.5435	0.94895	0.80724	0.96945
{'p10'}	}	0.11645	4.2417	1.0917	0.93681	1.2501
{'p20'}	}	0.50875	5.08	1.2515	1.072	1.7735
{'p25'}	}	0.75899	5.4247	1.3061	1.1504	2.0649
{'p30'}	}	1.0156	5.7325	1.3564	1.2011	2.3741
{'p40'}	}	1.6036	6.2932	1.4459	1.3198	3.0387
{'p50'}	}	2.2768	6.8406	1.5297	1.4423	3.8053
{'p60'}	}	3.0945	7.4051	1.6122	1.5771	4.7002
{'p70'}	}	4.113	8.0338	1.7042	1.7334	5.8225
{'p75'}	}	4.7604	8.3794	1.7554	1.8278	6.4985
{'p80'}	}	5.5142	8.7771	1.8143	1.9295	7.3239
{'p90'}	}	7.8048	9.8378	1.9756	2.2476	9.7629
{'p95'}	}	10.007	10.714	2.1161	2.5336	12.107
{'p99'}	}	14.9	12.348	2.407	3.1578	17.285
{'p99_9'}	}	21.501	14.13	2.7694	4.0322	24.216
{'p99_99'}	}	27.735	15.514	3.1037	4.8946	30.851
{'fl_cov_ap'}	}	11.305	6.5234	1.0466	1.0907	12.352
{'fl_cor_ap'}	}	1	0.89316	0.88579	0.60415	0.99902
{'fl_cov_v'}	}	6.5234	4.7186	0.76066	0.98362	7.2841
{'fl_cor_v'}	}	0.89316	1	0.99645	0.84334	0.9119
{'fl_cov_c'}	}	1.0466	0.76066	0.1235	0.15645	1.1701
{'fl_cor_c'}	}	0.88579	0.99645	1	0.82914	0.9055
{'fl_cov_y'}	}	1.0907	0.98362	0.15645	0.2883	1.2471
{'fl_cor_y'}	}	0.60415	0.84334	0.82914	1	0.63165
{'fl_cov_coh'}	}	12.352	7.2841	1.1701	1.2471	13.522
{'fl_cor_coh'}	}	0.99902	0.9119	0.9055	0.63165	1
{'fl_cov_savefraccoh'}		0.66084	0.46879	0.077707	0.0772	0.73855
{'fl_cor_savefraccoh'}		0.78009	0.85658	0.87766	0.57067	0.79716
{'fracByP0_01'}	}	0	-7.0657e-06	2.6272e-05	3.0716e-05	8.3673e-06
{'fracByP0_1'}	}	0	8.1733e-05	0.00058172	0.0003	0.00018482
{'fracByP1'}	}	0	0.0025825	0.0055755	0.0043105	0.0017358
{'fracByP5'}	}	1.3446e-07	0.020553	0.028388	0.023343	0.0084443
{'fracByP10'}	}	0.00082822	0.048923	0.059616	0.051792	0.020041
{'fracByP20'}	}	0.010119	0.11678	0.1368	0.1176	0.051426
{'fracByP25'}	}	0.019764	0.15445	0.17846	0.15402	0.071298
{'fracByP30'}	}	0.033198	0.19437	0.22195	0.19279	0.094487
{'fracByP40'}	}	0.072799	0.28088	0.31405	0.27516	0.15079
{'fracByP50'}	}	0.13186	0.37535	0.41129	0.36559	0.22202
{'fracByP60'}	}	0.21318	0.47748	0.51316	0.46495	0.30966
{'fracByP70'}	}	0.32222	0.58845	0.62103	0.57307	0.41837
{'fracByP75'}	}	0.39045	0.64744	0.67785	0.63075	0.48233
{'fracByP80'}	}	0.46786	0.7092	0.73555	0.69205	0.55399
{'fracByP90'}	}	0.66756	0.84275	0.8587	0.82726	0.72947
{'fracByP95'}	}	0.80166	0.91607	0.92521	0.90478	0.84112
{'fracByP99'}	}	0.94602	0.98111	0.98335	0.97699	0.95791
{'fracByP99_9'}	}	0.99264	0.99789	0.9981	0.99714	0.99438
{'fracByP99_99'}	}	0.99908	0.99977	0.99979	0.99966	0.9993

Chapter 3

Summarize Policy and Value

3.1 FF_SUMM_ND_ARRAY Examples

Go back to [fan's MEconTools Toolbox \(bookdown\)](#), [Matlab Code Examples Repository \(bookdown\)](#), or [Math for Econ with Matlab Repository \(bookdown\)](#).

This is the example vignette for function: `ff_summ_nd_array` from the [MEconTools Package](#). This function summarizes policy and value functions over states.

3.1.1 Test FF_SUMM_ND_ARRAY Defaults

Call the function with defaults.

```
ff_summ_nd_array();
```

group	marry	kids	mean_age_18	mean_age_19	mean_age_20	mean_age_21
1	0	1	0.53448	0.44448	0.5053	0.52914
2	1	1	0.4564	0.44512	0.44998	0.51775
3	0	2	0.52415	0.49903	0.48403	0.44429
4	1	2	0.49235	0.43684	0.44717	0.45226
5	0	3	0.4668	0.52676	0.49386	0.51855
6	1	3	0.47097	0.60345	0.58319	0.46238
7	0	4	0.55484	0.53601	0.53069	0.49323
8	1	4	0.5283	0.44091	0.53317	0.51062

3.1.2 Test FF_SUMM_ND_ARRAY with Random 2 Dimensional Matrix

Summarize over 6 dimensional array, iteratively change how many dimensions to group over.

First, generate matrix:

```
st_title = "Random 2D dimensional Array Testing Summarizing";
rng(123)
mn_polval = rand(5,4);
bl_print_table = true;
ar_st_stats = ["mean"];
cl_mp_datasetdesc = {};
cl_mp_datasetdesc{1} = containers.Map({'name', 'labval'}, ...
    {'a', linspace(0,1,size(mn_polval,1))});
cl_mp_datasetdesc{2} = containers.Map({'name', 'labval'}, ...
    {'z', linspace(-1,1,size(mn_polval,2))});
disp(mn_polval);
```

0.6965	0.4231	0.3432	0.7380
0.2861	0.9808	0.7290	0.1825
0.2269	0.6848	0.4386	0.1755
0.5513	0.4809	0.0597	0.5316
0.7195	0.3921	0.3980	0.5318

Second, show the entire matrix (no labels):

```
it_aggd = 0;
bl_row = 1;
ff_summ_nd_array(st_title, mn_polval, bl_print_table, ar_st_stats, it_aggd, bl_row);
```

xxx Random 2D dimensional Array Testing Summarizing xxxxxxxxxxxxxxxxxxxxxxxxx						mean
group	vardim2	mean_vardim1_1	mean_vardim1_2	mean_vardim1_3	mean_vardim1_4	mean
----	-----	-----	-----	-----	-----	---
1	1	0.69647	0.28614	0.22685	0.55131	0
2	2	0.42311	0.98076	0.68483	0.48093	0
3	3	0.34318	0.72905	0.43857	0.059678	0
4	4	0.738	0.18249	0.17545	0.53155	0

Third, rotate row and column, and now with labels:

```
it_aggd = 0;
bl_row = 1;
ar_permute = [2,1];
ff_summ_nd_array(st_title, mn_polval, bl_print_table, ar_st_stats, it_aggd, bl_row, ...
    cl_mp_datasetdesc, ar_permute);
```

xxx Random 2D dimensional Array Testing Summarizing xxxxxxxxxxxxxxxxxxxxxxxxx					
group	a	mean_z__1	mean_z__0_33333	mean_z_0_33333	mean_z_1
----	---	-----	-----	-----	-----
1	0	0.69647	0.42311	0.34318	0.738
2	0.25	0.28614	0.98076	0.72905	0.18249
3	0.5	0.22685	0.68483	0.43857	0.17545
4	0.75	0.55131	0.48093	0.059678	0.53155
5	1	0.71947	0.39212	0.39804	0.53183

Fourth, dimension one as columns, average over dim 2:

```
it_aggd = 1;
bl_row = 1;
ff_summ_nd_array(st_title, mn_polval, bl_print_table, ar_st_stats, it_aggd, bl_row, ...
    cl_mp_datasetdesc);
```

xxx Random 2D dimensional Array Testing Summarizing xxxxxxxxxxxxxxxxxxxxxxxxx					
group	x	mean_z__1	mean_z__0_33333	mean_z_0_33333	mean_z_1
----	-	-----	-----	-----	-----
1	1	0.49605	0.59235	0.3937	0.43186

Fifth, dimension one as rows, average over dim 2:

```
it_aggd = 1;
bl_row = 0;
ff_summ_nd_array(st_title, mn_polval, bl_print_table, ar_st_stats, it_aggd, bl_row, ...
    cl_mp_datasetdesc);
```

xxx Random 2D dimensional Array Testing Summarizing xxxxxxxxxxxxxxxxxxxxxxxxx							
group	z	sum	mean	std	coefvari	min	max

1	-1	2.4802	0.49605	0.22895	2.1666	0.22685	0.71947
2	-0.333333	2.9617	0.59235	0.24524	2.4154	0.39212	0.98076
3	0.333333	1.9685	0.3937	0.23907	1.6468	0.059678	0.72905
4	1	2.1593	0.43186	0.24575	1.7573	0.17545	0.738

Sixth, dimension two as rows, average over dim 1:

```
ar_permute = [2,1];
it_aggd = 1;
bl_row = 0;
ff_summ_nd_array(st_title, mn_polval, bl_print_table, ar_st_stats, it_aggd, bl_row, ...
    cl_mp_datasetdesc, ar_permute);
```

xxx Random 2D dimensional Array Testing Summarizing						xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx		
group	a	sum	mean	std	coefvari	min	max	
1	0	2.2007	0.55019	0.19636	2.8019	0.34318	0.738	
2	0.25	2.1784	0.54461	0.37514	1.4518	0.18249	0.98076	
3	0.5	1.5257	0.38143	0.23212	1.6432	0.17545	0.68483	
4	0.75	1.6235	0.40587	0.23269	1.7443	0.059678	0.55131	
5	1	2.0415	0.51036	0.15361	3.3226	0.39212	0.71947	

3.1.3 Test FF_SUMM_ND_ARRAY with Random 6 Dimensional Matrix

Summarize over 6 dimensional array, iteratively change how many dimensions to group over.

First, generate matrix:

```
st_title = "Random ND dimensional Array Testing Summarizing";
rng(123)
mn_polval = rand(8,7,6,5,4,3);
bl_print_table = true;
ar_st_stats = ["mean"];
```

Second, summarize over the first four dimensions, row group others:

```
it_aggd = 4;
bl_row = 0;
ff_summ_nd_array(st_title, mn_polval, bl_print_table, ar_st_stats, it_aggd, bl_row);
```

xxx Random ND dimensional Array Testing Summarizing						xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx		
group	vardim5	vardim6	sum	mean	std	coefvari	min	max
1	1	1	836.78	0.49808	0.29255	1.7026	8.1888e-05	0.99964
2	2	1	842.15	0.50128	0.28968	1.7305	6.7838e-05	0.99936
3	3	1	831.45	0.49491	0.28851	1.7154	0.00091373	0.99989
4	4	1	843.9	0.50232	0.28154	1.7842	0.00012471	0.99731
5	1	2	838.99	0.4994	0.2911	1.7156	0.00029749	0.99938
6	2	2	830.81	0.49453	0.28634	1.7271	0.00027113	0.9992
7	3	2	832.59	0.49559	0.28682	1.7279	0.00035994	0.99936
8	4	2	820.42	0.48835	0.29032	1.6821	0.00096259	0.99896
9	1	3	870.56	0.51819	0.29111	1.7801	0.0010616	0.99951
10	2	3	854.68	0.50874	0.28458	1.7877	0.001884	0.99965
11	3	3	838.29	0.49898	0.2891	1.726	0.0019192	0.99945
12	4	3	842.83	0.50169	0.2877	1.7438	0.00016871	0.99963

Third, summarize over the first four dimensions, column group 5th, and row group others:

```

it_aggd = 4;
bl_row = 1;
ff_summ_nd_array(st_title, mn_polval, bl_print_table, ["sum"], it_aggd, bl_row);

xxx Random ND dimensional Array Testing Summarizing xxxxxxxxxxxxxxxxxxxxxxxxx
group    vardim6    sum_vardim5_1    sum_vardim5_2    sum_vardim5_3    sum_vardim5_4
-----
1        1          836.78         842.15         831.45         843.9
2        2          838.99         830.81         832.59         820.42
3        3          870.56         854.68         838.29         842.83

```

Fourth, summarize over the first five dimensions, column group 6th, no row groups:

```

it_aggd = 5;
bl_row = 1;
ff_summ_nd_array(st_title, mn_polval, bl_print_table, ["mean", "std"], it_aggd, bl_row);

xxx Random ND dimensional Array Testing Summarizing xxxxxxxxxxxxxxxxxxxxxxxxx
group    x      mean_vardim6_1    mean_vardim6_2    mean_vardim6_3    std_vardim6_1    std_vardim6_2
-----
1        1          0.49915       0.49447        0.5069        0.28805       0.28862

```

Fifth, summarize over all six dimensions, summary statistics over the entire dataframe:

```

it_aggd = 6;
bl_row = 0;
ff_summ_nd_array(st_title, mn_polval, bl_print_table, ar_st_stats, it_aggd, bl_row);

xxx Random ND dimensional Array Testing Summarizing xxxxxxxxxxxxxxxxxxxxxxxxx
group    x      sum      mean      std      coefvari      min      max
-----
1        1      10083   0.50017   0.28831   1.7349   6.7838e-05   0.99989

```

3.1.4 Test FF_SUMM_ND_ARRAY with Random 7 Dimensional Matrix with All Parameters

Given a random seven dimensional matrix, average over the 2nd, 4th and 5th dimensionals. Show as row groups the 3, 6 and 7th dimensions, and row groups the 1st dimension. Show Coefficient of Variation only.

```

st_title = "avg VALUE 2+4+5th dims. groups 3+6+7th dims, and row groups the 1st dim.";
rng(123)
mn_polval = rand(3,10,2,10,10,2,3);
ar_permute = [2,4,5,1,3,6,7];
bl_print_table = true;
ar_st_stats = ["coefvari"];
it_aggd = 3; % mean over 3 dims
bl_row = 1; % one var for row group
cl_mp_datasetdesc = {};
cl_mp_datasetdesc{1} = containers.Map({'name', 'labval'}, ...
    {'age', [18, 19, 20]});
cl_mp_datasetdesc{2} = containers.Map({'name', 'labval'}, ...
    {'savings', linspace(0,1,10)});
cl_mp_datasetdesc{3} = containers.Map({'name', 'labval'}, ...
    {'borrsave', [-1,+1]});
cl_mp_datasetdesc{4} = containers.Map({'name', 'labval'}, ...
    {'shocka', linspace(-5,5,10)});
cl_mp_datasetdesc{5} = containers.Map({'name', 'labval'}, ...

```

```

{'shockb', linspace(-5,5,10)}));
cl_mp_datasetdesc{6} = containers.Map({'name', 'labval'}, ...
    {'marry', [0,1]}));
cl_mp_datasetdesc{7} = containers.Map({'name', 'labval'}, ...
    {'region', [1,2,3]});
% call function
ff_summ_nd_array(st_title, mn_polval, bl_print_table, ar_st_stats, it_aggd, bl_row, cl_mp_datasetdes
xxx avg VALUE 2+4+5th dims. groups 3+6+7th dims, and row groups the 1st dim. xxxxxxxxxxxxxxxxxxxxxxxx
group    borrsave    marry    region    cv_age_18    cv_age_19    cv_age_20
-----
1        -1          0          1          1.7607      1.7534      1.7065
2         1          0          1          1.6566      1.7501      1.7042
3        -1          1          1          1.6608      1.7658      1.7291
4         1          1          1          1.756       1.7479      1.7606
5        -1          0          2          1.7314      1.7506      1.786
6         1          0          2          1.7347      1.728       1.738
7        -1          1          2          1.7811      1.755       1.7568
8         1          1          2          1.7445      1.7398      1.7746
9        -1          0          3          1.7025      1.7286      1.69
10        1          0          3          1.74       1.7549      1.7356
11        -1          1          3          1.7147      1.7287      1.7341
12        1          1          3          1.7919      1.7313      1.7452

```


Chapter 4

Distributional Analysis

4.1 FF_SIMU_STATS Examples

Go back to [fan's MEconTools Toolbox \(bookdown\)](#), [Matlab Code Examples Repository \(bookdown\)](#), or [Math for Econ with Matlab Repository \(bookdown\)](#).

This is the example vignette for function: `ff_simu_stats` from the [MEconTools Package](#). This is a gate-way function that computes mean, percentiles, covariance etc between several variables.

4.1.1 Test FF_SIMU_STATS Defaults

Call the function with defaults.

```
ff_simu_stats();
```

OriginalVariableNames	cl_mt_pol_a	cl_mt_pol_c
{'mean'}	-0.11081	8.8423
{'sd'}	4.1239	6.5845
{'coefofvar'}	-37.215	0.74466
{'min'}	-7	-6.3772
{'max'}	9	21.786
{'pYis0'}	0.064259	0
{'pYls0'}	0.54867	0.027329
{'pYgr0'}	0.38707	0.97267
{'pYisMINY'}	0.051764	0.015232
{'pYisMAXY'}	0.027329	0.046484
{'p1'}	-7	-6.3772
{'p10'}	-6	0.27238
{'p25'}	-3	5.2138
{'p50'}	-1	6.5321
{'p75'}	3	13.799
{'p90'}	5	16.887
{'p99'}	9	21.786
{'fl_cov_cl_mt_pol_a'}	17.007	-22.084
{'fl_cor_cl_mt_pol_a'}	1	-0.81327
{'fl_cov_cl_mt_pol_c'}	-22.084	43.356
{'fl_cor_cl_mt_pol_c'}	-0.81327	1
{'fracByP1'}	3.2699	-0.010985
{'fracByP10'}	5.9889	-0.013362
{'fracByP25'}	14.165	0.041007
{'fracByP50'}	16.208	0.1893

{'fracByP75'}	}	12.702	0.59539
{'fracByP90'}	}	6.6611	0.8307
{'fracByP99'}	}	1	1

4.1.2 Test FF_SIMU_STATS Four States-Points Matrix

Over some (a,z) states that is 3 by 3, c matrix, generate all stats

```
% Set Parameters
mt_x_of_s = [1, 2, 3.0;...
              3, 1, 1.5;...
              4, 3, 2.0];
mt_y_of_s = [2, -10, 9.0;...
              5, 1.1, 3.0;...
              1, 3, -1.5];
mt_z_of_s = [1.1, 2, 3.3;...
              2.3, 1, 1.5;...
              4, 2.5, 2.0];
mp_cl_mt_xyz_of_s = containers.Map('KeyType','char', 'ValueType','any');
mp_cl_mt_xyz_of_s('cl_mt_x_of_s') = {mt_x_of_s, zeros(1)};
mp_cl_mt_xyz_of_s('cl_mt_y_of_s') = {mt_y_of_s, zeros(1)};
mp_cl_mt_xyz_of_s('cl_mt_z_of_s') = {mt_z_of_s, zeros(1)};
mp_cl_mt_xyz_of_s('ar_st_y_name') = ["cl_mt_x_of_s", "cl_mt_y_of_s", "cl_mt_z_of_s"];
% Mass
rng(123);
mt_f_of_s = rand(size(mt_x_of_s));
mt_f_of_s = mt_f_of_s/sum(mt_f_of_s, 'all');
% Call Function
mp_cl_mt_xyz_of_s_out = ff_simu_stats(mt_f_of_s, mp_cl_mt_xyz_of_s);
```

xxx tb_outcomes: all stats xxx

OriginalVariableNames	cl_mt_x_of_s	cl_mt_y_of_s	cl_mt_z_of_s
{'mean'}	2.0763	1.9323	2.0668
{'sd'}	0.9071	5.2239	0.9042
{'coefofvar'}	0.43688	2.7034	0.43749
{'min'}	1	-10	1
{'max'}	4	9	4
{'pYiso'}	0	0	0
{'pYls0'}	0	0.20441	0
{'pYgro'}	1	0.79559	1
{'pYisMINY'}	0.28039	0.10917	0.14247
{'pYisMAXY'}	0.044922	0.19422	0.044922
{'p1'}	1	-10	1
{'p10'}	1	-10	1
{'p25'}	1	1.1	1.1
{'p50'}	2	2	2
{'p75'}	3	5	2.5
{'p90'}	3	9	3.3
{'p99'}	4	9	4
{'fl_cov_cl_mt_x_of_s'}	0.82282	1.589	0.78646
{'fl_cor_cl_mt_x_of_s'}	1	0.33534	0.95887
{'fl_cov_cl_mt_y_of_s'}	1.589	27.289	1.8353
{'fl_cor_cl_mt_y_of_s'}	0.33534	1	0.38856
{'fl_cov_cl_mt_z_of_s'}	0.78646	1.8353	0.81758
{'fl_cor_cl_mt_z_of_s'}	0.95887	0.38856	1
{'fracByP1'}	0.13504	-0.56498	0.068934
{'fracByP10'}	0.13504	-0.56498	0.068934

{'fracByP25'}	}	0.13504	-0.53456	0.14234
{'fracByP50'}	}	0.42991	-0.39181	0.43856
{'fracByP75'}	}	0.91346	0.095425	0.60296
{'fracByP90'}	}	0.91346	1	0.91306
{'fracByP99'}	}	1	1	1

4.1.3 Test FF_SIMU_STATS Four States-Points Matrix Single Column Inputs

Same as before, but now inputs are single column, should have identical results:

```
% Array Inputs
mp_cl_ar_xyz_of_s = containers.Map('KeyType','char', 'ValueType','any');
mp_cl_mt_xyz_of_s('cl_mt_x_of_s') = {mt_x_of_s(:), zeros(1)};
mp_cl_mt_xyz_of_s('cl_mt_y_of_s') = {mt_y_of_s(:), zeros(1)};
mp_cl_mt_xyz_of_s('cl_mt_z_of_s') = {mt_z_of_s(:), zeros(1)};
mp_cl_mt_xyz_of_s('ar_st_y_name') = ["cl_mt_x_of_s", "cl_mt_y_of_s", "cl_mt_z_of_s"];
% Call Function
mp_cl_mt_xyz_of_s_out = ff_simu_stats(mt_f_of_s(:), mp_cl_mt_xyz_of_s);
```

OriginalVariableNames	cl_mt_x_of_s	cl_mt_y_of_s	cl_mt_z_of_s
{'mean'}	2.0763	1.9323	2.0668
{'sd'}	0.9071	5.2239	0.9042
{'coefofvar'}	0.43688	2.7034	0.43749
{'min'}	1	-10	1
{'max'}	4	9	4
{'pYis0'}	0	0	0
{'pYls0'}	0	0.20441	0
{'pYgr0'}	1	0.79559	1
{'pYisMINY'}	0.28039	0.10917	0.14247
{'pYisMAXY'}	0.044922	0.19422	0.044922
{'p1'}	1	-10	1
{'p10'}	1	-10	1
{'p25'}	1	1.1	1.1
{'p50'}	2	2	2
{'p75'}	3	5	2.5
{'p90'}	3	9	3.3
{'p99'}	4	9	4
{'fl_cov_cl_mt_x_of_s'}	0.82282	1.589	0.78646
{'fl_cor_cl_mt_x_of_s'}	1	0.33534	0.95887
{'fl_cov_cl_mt_y_of_s'}	1.589	27.289	1.8353
{'fl_cor_cl_mt_y_of_s'}	0.33534	1	0.38856
{'fl_cov_cl_mt_z_of_s'}	0.78646	1.8353	0.81758
{'fl_cor_cl_mt_z_of_s'}	0.95887	0.38856	1
{'fracByP1'}	0.13504	-0.56498	0.068934
{'fracByP10'}	0.13504	-0.56498	0.068934
{'fracByP25'}	0.13504	-0.53456	0.14234
{'fracByP50'}	0.42991	-0.39181	0.43856
{'fracByP75'}	0.91346	0.095425	0.60296
{'fracByP90'}	0.91346	1	0.91306
{'fracByP99'}	1	1	1

4.1.4 Test FF_SIMU_STATS Print Many Details

The Same As before, but now control which percentiles and other details to display.

```
% Array Inputs
mp_cl_ar_xyz_of_s = containers.Map('KeyType','char', 'ValueType','any');
mp_cl_ar_xyz_of_s('cl_ar_x_of_s') = {mt_x_of_s(:), zeros(1)};
mp_cl_ar_xyz_of_s('cl_ar_z_of_s') = {mt_z_of_s(:), zeros(1)};
mp_cl_ar_xyz_of_s('ar_st_y_name') = ["cl_ar_x_of_s", "cl_ar_z_of_s"];

% controls
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_display_detail') = false;
mp_support('bl_display_final') = true;
mp_support('bl_display_drvm2outcomes') = false;
mp_support('ar_fl_percentiles') = [25 50 75];
mp_support('bl_display_drvstats') = true;
mp_support('bl_display_drvm2covcor') = false;

% Call Function
mp_cl_mt_xyz_of_s_out = ff_simu_stats(mt_f_of_s(:), mp_cl_ar_xyz_of_s, mp_support);

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
Summary Statistics for: cl_ar_x_of_s
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
-----
fl_choice_mean
    2.0763

fl_choice_sd
    0.9071

fl_choice_coefofvar
    0.4369

fl_choice_prob_zero
    0

fl_choice_prob_below_zero
    0

fl_choice_prob_above_zero
    1

fl_choice_prob_max
    0.0449

tb_disc_cumu
    cl_ar_x_of_sDiscreteVal    cl_ar_x_of_sDiscreteValProbMass    CDF    cumsumFrac
    -----
    1                            0.28039                      28.039   0.13504
    1.5                          0.13561                      41.6    0.23301
    2                            0.20441                      62.041   0.42991
    3                            0.33466                      95.508   0.91346
    4                            0.044922                     100      1

    cl_ar_x_of_sDiscreteVal    cl_ar_x_of_sDiscreteValProbMass    CDF    cumsumFrac
    -----
    1                            0.28039                      28.039   0.13504
```

1.5	0.13561	41.6	0.23301
2	0.20441	62.041	0.42991
3	0.33466	95.508	0.91346
4	0.044922	100	1
<hr/>			
tb_prob_drv			
percentiles	cl_ar_x_of_sDiscreteValPercentileValues	fracOfSumHeldBelowThisPercentile	
<hr/>			
25	1		0.13504
50	2		0.42991
75	3		0.91346
<hr/>			
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx			
Summary Statistics for: cl_ar_z_of_s			
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx			
<hr/>			
fl_choice_mean			
	2.0668		
<hr/>			
fl_choice_sd			
	0.9042		
<hr/>			
fl_choice_coefofvar			
	0.4375		
<hr/>			
fl_choice_prob_zero			
	0		
<hr/>			
fl_choice_prob_below_zero			
	0		
<hr/>			
fl_choice_prob_above_zero			
	1		
<hr/>			
fl_choice_prob_max			
	0.0449		
<hr/>			
tb_disc_cumu			
cl_ar_z_of_sDiscreteVal	cl_ar_z_of_sDiscreteValProbMass	CDF	cumsumFrac
<hr/>			
1	0.14247	14.247	0.068934
1.1	0.13792	28.039	0.14234
1.5	0.13561	41.6	0.24076
2	0.20441	62.041	0.43856
2.3	0.056663	67.708	0.50162
2.5	0.083786	76.086	0.60296
3.3	0.19422	95.508	0.91306
4	0.044922	100	1
<hr/>			
cl_ar_z_of_sDiscreteVal	cl_ar_z_of_sDiscreteValProbMass	CDF	cumsumFrac
<hr/>			
1	0.14247	14.247	0.068934
1.1	0.13792	28.039	0.14234
1.5	0.13561	41.6	0.24076

```

2                               0.20441      62.041     0.43856
2.3                            0.056663    67.708     0.50162
2.5                            0.083786    76.086     0.60296
3.3                            0.19422     95.508     0.91306
4                               0.044922    100          1

tb_prob_drv
percentiles   cl_ar_z_of_sDiscreteValPercentileValues   fracOfSumHeldBelowThisPercentile
-----  -----  -----
25                      1.1          0.14234
50                      2            0.43856
75                      2.5          0.60296

xxx tb_outcomes: all stats xxx
OriginalVariableNames   cl_ar_x_of_s   cl_ar_z_of_s
-----  -----  -----
{'mean'}                2.0763       2.0668
{'sd'}                  0.9071       0.9042
{'coefofvar'}            0.43688      0.43749
{'min'}                 1             1
{'max'}                 4             4
{'pYis0'}                0             0
{'pYls0'}                0             0
{'pYgr0'}                1             1
{'pYisMINY'}             0.28039      0.14247
{'pYisMAXY'}             0.044922     0.044922
{'p25'}                  1             1.1
{'p50'}                  2             2
{'p75'}                  3             2.5
{'fl_cov_cl_ar_x_of_s'}  0.82282      0.78646
{'fl_cor_cl_ar_x_of_s'}  1             0.95887
{'fl_cov_cl_ar_z_of_s'}  0.78646      0.81758
{'fl_cor_cl_ar_z_of_s'}  0.95887      1
{'fracByP25'}             0.13504      0.14234
{'fracByP50'}             0.42991      0.43856
{'fracByP75'}             0.91346      0.60296

```

4.2 FF_DISC_RAND_VAR_STATS Examples

Go back to [fan's MEconTools Toolbox \(bookdown\)](#), [Matlab Code Examples Repository \(bookdown\)](#), or [Math for Econ with Matlab Repository \(bookdown\)](#).

This is the example vignette for function: `ff_disc_rand_var_stats` from the [MEconTools Package](#). This function summarizes statistics of matrixes stored in a container map, as well as scalar, string, function and other values stored in container maps.

4.2.1 Test FF_DISC_RAND_VAR_STATS Defaults

Call the function with defaults.

```
ff_disc_rand_var_stats();
```

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
Summary Statistics for: binom
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

```

fl_choice_mean
-1.0000

fl_choice_sd
2.5100

fl_choice_coefofvar
-2.5100

fl_choice_prob_zero
0.1416

fl_choice_prob_below_zero
0.5888

fl_choice_prob_above_zero
0.2696

fl_choice_prob_max
2.0589e-16

tb_disc_cumu
binomDiscreteVal      binomDiscreteValProbMass          CDF      cumsumFrac
-----  -----
-10                  2.2539e-05                0.0022539  0.00022539
-9                   0.00028979              0.031233   0.0028335
-8                   0.0018008               0.21132    0.01724
-7                   0.0072034               0.93166    0.067664
-6                   0.020838                3.0155     0.19269
-5                   0.04644                 7.6595     0.42489
-4                   0.082928                15.952     0.75661
-3                   0.12185                 28.138    1.1222
-2                   0.15014                 43.152     1.4224
-1                   0.15729                 58.881    1.5797

binomDiscreteVal      binomDiscreteValProbMass          CDF      cumsumFrac
-----  -----
11                  6.0392e-06                100       1
12                  1.0588e-06              100       1
13                  1.5784e-07              100       1
14                  1.973e-08               100       1
15                  2.0293e-09              100       1
16                  1.6725e-10              100       1
17                  1.0619e-11              100       1
18                  4.8762e-13              100       1
19                  1.4412e-14              100       1
20                  2.0589e-16              100       1

tb_prob_drv
percentiles      binomDiscreteValPercentileValues      fracOfSumHeldBelowThisPercentile
-----  -----
0.1                  -8                      0.01724
1                     -6                      0.19269
5                     -5                      0.42489
10                    -4                      0.75661

```

15	-4	0.75661
20	-3	1.1222
25	-3	1.1222
35	-2	1.4224
50	-1	1.5797
65	0	1.5797
75	1	1.4694
80	1	1.4694
85	2	1.3197
90	2	1.3197
95	3	1.1865
99	5	1.0412
99.9	7	1.0052

4.2.2 Test FF_DISC_RAND_VAR_STATS 0 and 1 Random Variable

The simplest discrete random variable has two values, zero or one. The probability of zero is 30 percent, and 70 percent is the probability of one.

```
% Parameters
% 1. specify the random variable
st_var_name = 'bernoulli';
ar_choice_unique_sorted = [0, 1];
ar_choice_prob = [0.3, 0.7];
% 2. percentiles of interest
ar_fl_percentiles = [0.1 5 25 50 75 95 99.9];
% 3. print results
bl_display_drvstats = true;
% Call Function
[ds_stats_map] = ff_disc_rand_var_stats(st_var_name, ...
    ar_choice_unique_sorted, ar_choice_prob, ...
    ar_fl_percentiles, bl_display_drvstats);

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
Summary Statistics for: bernoulli
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
-----
fl_choice_mean
0.7000

fl_choice_sd
0.4583

fl_choice_coefofvar
0.6547

fl_choice_prob_zero
0.3000

fl_choice_prob_below_zero
0

fl_choice_prob_above_zero
0.7000

fl_choice_prob_max
0.7000
```

tb_disc_cumu		CDF	cumsumFrac
bernoulliDiscreteVal	bernoulliDiscreteValProbMass	---	---
0	0.3	30	0
1	0.7	100	1
tb_prob_drv		fracOfSumHeldBelowThisPercentile	
percentiles	bernoulliDiscreteValPercentileValues	fracOfSumHeldBelowThisPercentile	
0.1	0	0	
5	0	0	
25	0	0	
50	1	1	
75	1	1	
95	1	1	
99.9	1	1	

4.2.3 Test FF_DISC RAND VAR STATS with Poisson

Poisson random variable, with mean equals to ten, summarize over umsymmetric percentiles. Note that the poisson random variable has no upper bound.

```
% Parameters
% 1. specify the random variable
st_var_name = 'poisson';
mu = 10;
ar_choice_unique_sorted = 0:1:50;
ar_choice_prob = poisspdf(ar_choice_unique_sorted, mu);
% 2. percentiles of interest, unsymmetric
ar_fl_percentiles = [0.1 5 10 25 50 90 95 99 99.9 99.99 99.999 99.9999];
% 3. print results
bl_display_drvstats = true;
% Call Function
[ds_stats_map] = ff_disc_rand_var_stats(st_var_name, ...
    ar_choice_unique_sorted, ar_choice_prob, ...
    ar_fl_percentiles, bl_display_drvstats);

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
Summary Statistics for: poisson
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
-----

fl_choice_mean
    10

fl_choice_sd
    3.1623

fl_choice_coefofvar
    0.3162
```

```
f1_choice_prob_zero
4.5400e-05
```

```
f1_choice_prob_below_zero
0
```

```
f1_choice_prob_above_zero
1.0000
```

```
f1_choice_prob_max
1.4927e-19
```

tb_disc_cumu

poissonDiscreteVal	poissonDiscreteValProbMass	CDF	cumsumFrac
0	4.54e-05	0.00454	0
1	0.000454	0.04994	4.54e-05
2	0.00227	0.27694	0.0004994
3	0.0075667	1.0336	0.0027694
4	0.018917	2.9253	0.010336
5	0.037833	6.7086	0.029253
6	0.063055	13.014	0.067086
7	0.090079	22.022	0.13014
8	0.1126	33.282	0.22022
9	0.12511	45.793	0.33282

poissonDiscreteVal	poissonDiscreteValProbMass	CDF	cumsumFrac
41	1.3571e-13	100	1
42	3.2313e-14	100	1
43	7.5146e-15	100	1
44	1.7079e-15	100	1
45	3.7953e-16	100	1
46	8.2506e-17	100	1
47	1.7554e-17	100	1
48	3.6572e-18	100	1
49	7.4636e-19	100	1
50	1.4927e-19	100	1

tb_prob_drv

percentiles	poissonDiscreteValPercentileValues	fracOfSumHeldBelowThisPercentile
0.1	2	0.0004994
5	5	0.029253
10	6	0.067086
25	8	0.22022
50	10	0.45793
90	14	0.86446
95	15	0.91654
99	18	0.98572
99.9	21	0.99841
99.99	24	0.99988
99.999	26	0.99998
100	28	1

```
% Print out full Stored Matrix
% Note that the outputs are single row arrays.
ff_container_map_display(ds_stats_map, 100, 100)

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: ds_stats_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

          i      idx     ndim    numel   rowN   colN     sum   mean   st
          -      ---     ----    -----   ----   ----   -----   -----   -----
ar_choice_perc_fracheld  1       1       2       12      1      12      7.54  0.62833  0.
ar_choice_percentiles    2       2       2       12      1      12      177   14.75   8.7
ar_fl_percentiles        3       3       2       12      1      12    773.99  64.499  42.

xxx TABLE:ar_choice_perc_fracheld xxxxxxxxxxxxxxxxxxxx
      c1      c2      c3      c4      c5      c6      c7      c8
      -----  -----  -----  -----  -----  -----  -----  -----
r1  0.0004994  0.029253  0.067086  0.22022  0.45793  0.86446  0.91654  0.98572

xxx TABLE:ar_choice_percentiles xxxxxxxxxxxxxxxxxxxx
      c1      c2      c3      c4      c5      c6      c7      c8      c9      c10     c11     c12
      --      --      --      --      --      --      --      --      --      ---     ---     ---
r1  2       5       6       8       10      14      15      18      21      24      26      28

xxx TABLE:ar_fl_percentiles xxxxxxxxxxxxxxxxxxxx
      c1      c2      c3      c4      c5      c6      c7      c8      c9      c10     c11     c12
      ---     ---     ---     ---     ---     ---     ---     ---     ---     -----  -----  -----
r1  0.1     5      10      25      50      90      95      99     99.9    99.99   99.999  100

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: ds_stats_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

          i      idx     value
          --      ---   -----
fl_choice_coefofvar       1       4      0.31623
fl_choice_max             2       5      50
fl_choice_mean            3       6      10
fl_choice_min              4       7      0
fl_choice_prob_above_zero 5       8      0.99995
fl_choice_prob_below_zero 6       9      0
fl_choice_prob_max        7      10      1.4927e-19
fl_choice_prob_min        8      11      4.54e-05
fl_choice_prob_zero       9      12      4.54e-05
fl_choice_sd              10     13      3.1623
```

4.3 FF_DISC RAND VAR MASS2OUTCOMES Examples

Go back to [fan's MEconTools Toolbox \(bookdown\)](#), [Matlab Code Examples Repository \(bookdown\)](#), or [Math for Econ with Matlab Repository \(bookdown\)](#).

This is the example vignette for function: [ff_disc_rand_var_mass2outcomes](#) from the [MEconTools Package](#). This function generates sorted discrete random variable from state-space joint distri-

bution.

4.3.1 Test FF_DISC_RAND_VAR_MASS2OUTCOMES Defaults

Call the function with defaults.

```
ff_disc_rand_var_mass2outcomes();
```

```
INPUT f(a,z): mt_dist_bystates
 0.0289  0.0465  0.0228  0.0036  0.0001
 0.0241  0.0930  0.0857  0.0241  0.0015
 0.0080  0.0744  0.1285  0.0643  0.0074
 0.0013  0.0297  0.0964  0.0857  0.0186
 0.0001  0.0059  0.0361  0.0571  0.0232
 0.0000  0.0005  0.0054  0.0152  0.0116

INPUT y(a,z): mt_choice_bystates
 -5   -4   -5   -4   -4
 -3   -2   -3   -2   -3
 -1   -1   -1   0   0
 1    1    2    3    1
 4    3    3    4    3
 5    6    5    6    6

OUTPUT f(y): ar_choice_prob_byY
 0.0518
 0.0502
 0.1113
 0.1171
 0.2109
 0.0717
 0.0497
 0.0964
 0.1510
 0.0572
 0.0054
 0.0273

OUTPUT f(y,z): mt_choice_prob_byYZ
 0.0289      0     0.0228      0      0
 0     0.0465      0     0.0036  0.0001
 0.0241      0     0.0857      0  0.0015
 0     0.0930      0     0.0241      0
 0.0080      0.0744  0.1285      0      0
 0       0      0.0643  0.0074
 0.0013      0.0297      0      0  0.0186
 0       0     0.0964      0      0
 0     0.0059     0.0361  0.0857  0.0232
 0.0001      0      0     0.0571      0
 0.0000      0     0.0054      0      0
 0     0.0005      0     0.0152  0.0116

OUTPUT f(y,a): mt_choice_prob_byYA
 0.0518      0      0      0      0      0
 0.0502      0      0      0      0      0
 0     0.1113      0      0      0      0
 0     0.1171      0      0      0      0
 0       0     0.2109      0      0      0
 0       0     0.0717      0      0      0
```

```

0         0         0   0.0497      0         0
0         0         0   0.0964      0         0
0         0         0   0.0857   0.0653      0
0         0         0       0   0.0572      0
0         0         0       0       0   0.0054
0         0         0       0       0   0.0273

OUTPUT f(y) and y in table: tb_choice_drv_cur_byY
binomtestOutcomes    probMassFunction
-----
-5           0.051764
-4           0.050217
-3           0.11126
-2           0.11706
-1           0.21092
0            0.071696
1            0.049682
2            0.096388
3            0.15102
4            0.057231
5            0.0054256
6            0.027329

```

4.3.2 Test FF_DISC RAND VAR MASS2OUTCOMES Four States-Points

Over some (a,z) states that is 2 by 2, matrix or vectorized inputs identical results.

```

% Set Parameters
st_y_name = 'consumption';
% consumption matrix: c(a,z)
mt_c_of_s = [1,2;3,1];
% stationary mass over assets adn shocks: f(a,z)
mt_f_of_s = rand(size(mt_c_of_s));
mt_f_of_s = mt_f_of_s/sum(mt_f_of_s, 'all');
% Call Function
[ar_f_of_y, ar_y_unique_sorted] = ...
    ff_disc_rand_var_mass2outcomes(st_y_name, mt_c_of_s, mt_f_of_s);
% print
disp([ar_f_of_y ar_y_unique_sorted]);

```

0.4039	1.0000
0.2971	2.0000
0.2990	3.0000

Same as before, but now inputs are single column:

```

% Call Function
[ar_f_of_y, ar_y_unique_sorted] = ...
    ff_disc_rand_var_mass2outcomes(st_y_name, mt_c_of_s(:, ), mt_f_of_s);
disp([ar_f_of_y ar_y_unique_sorted]);

```

0.4039	1.0000
0.2971	2.0000
0.2990	3.0000

4.3.3 Test FF_DISC_RAND_VAR_MASS2OUTCOMES Conditional Mass Outputs

Same inputs as before, but now, also output additional conditional statistis, $f(y, a)$, where a is the row state variable for $f(a, z)$. For conditional statistics, must provide matrix based inputs.

```
% Set Parameters
st_y_name = 'consumption';
% consumption matrix: c(a,z)
mt_c_of_s = [1,2,0.5;
              3,1,2.0];
% stationary mass over assets adn shocks: f(a,z)
mt_f_of_s = rand(size(mt_c_of_s));
mt_f_of_s = mt_f_of_s/sum(mt_f_of_s, 'all');
% Call Function
[ar_f_of_y, ar_y_unique_sorted, mt_f_of_y_srow, mt_f_of_y_scol] = ...
    ff_disc_rand_var_mass2outcomes(st_y_name, mt_c_of_s, mt_f_of_s);
% print
disp([ar_f_of_y ar_y_unique_sorted]);

0.2695    0.5000
0.3765    1.0000
0.2649    2.0000
0.0891    3.0000

disp(mt_f_of_y_srow);

0.2695      0
0.1215    0.2550
0.1217    0.1432
0        0.0891

disp(mt_f_of_y_scol);

0        0    0.2695
0.1215    0.2550      0
0        0.1217    0.1432
0.0891      0        0
```

4.4 FF_DISC_RAND_VAR_MASS2COVCOR Examples

Go back to fan's MEconTools Toolbox ([bookdown](#)), Matlab Code Examples Repository ([bookdown](#)), or Math for Econ with Matlab Repository ([bookdown](#)).

This is the example vignette for function: `ff_disc_rand_var_mass2covcor` from the **MEconTools Package**. This function calculates covariance and correlation based for two discrete random variables.

4.4.1 Test FF_DISC_RAND_VAR_MASS2COVCOR Defaults

Call the function with defaults.

```
ff_disc_rand_var_mass2covcor();
```

```
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: covvar_input_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
          i     idx    ndim   numel    rowN    colN    sum     mean      std      coef
          -     ---    ----   -----    ----    ----   -----  -----  -----  -----  -----
```

mt_f_of_s	1	5	2	30	6	5	1	0.033333	0.035743	1.0
mt_x_of_s	2	6	2	30	6	5	25	0.83333	5.3051	6.3
mt_y_of_s	3	7	2	30	6	5	249.78	8.3259	7.1913	0.86

xxx TABLE:mt_f_of_s xxxxxxxxxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5
r1	0.028917	0.046484	0.022848	0.0036146	0.000119
r2	0.024097	0.092967	0.085679	0.024097	0.0014875
r3	0.0080324	0.074374	0.12852	0.064259	0.0074374
r4	0.0013387	0.02975	0.096388	0.085679	0.018593
r5	0.00011156	0.0059499	0.036146	0.057119	0.023242
r6	3.7187e-06	0.00047599	0.0054218	0.015232	0.011621

xxx TABLE:mt_x_of_s xxxxxxxxxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5
r1	-7	-6	-7	-6	-6
r2	-5	-3	-5	-3	-4
r3	-2	-1	-1	0	-1
r4	2	2	3	4	2
r5	6	5	5	6	5
r6	8	9	7	9	9

xxx TABLE:mt_y_of_s xxxxxxxxxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5
r1	13.231	21.786	18.136	19.35	13.901
r2	9.946	16.887	9.6914	15.71	8.6906
r3	16.255	6.2166	13.799	5.2138	11.641
r4	12.628	2.7525	6.5321	0.27238	13.357
r5	5.8844	4.0352	6.05	0.14102	0.50318
r6	3.5617	-0.72091	5.1855	-6.3772	-4.4805

xx
CONTAINER NAME: covvar_input_map Scalars
xx

i	idx	value
-	---	-----
fl_x_mean	1	-0.11081
fl_x_sd	2	4.1239
fl_y_mean	3	8.8423
fl_y_sd	4	6.5845

xx
CONTAINER NAME: covvar_output_map ND Array (Matrix etc)
xx

	i	idx	ndim	numel	rowN	colN	sum	mean
mt_cov_component_weighted	1	1	2	30	6	5	-22.084	-0.73612

mt_x_devi_from_mean	2	2	2	30	6	5	28.324	0.94415
mt_x_y_multiply	3	3	2	30	6	5	-939.63	-31.321
mt_y_devi_from_mean	4	4	2	30	6	5	-15.493	-0.51644

xxx TABLE:mt_cov_component_weighted xxxxxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5
r1	-0.87434	-3.5432	-1.4628	-0.22368	-0.0035451
r2	-0.13003	-2.1607	-0.35565	-0.47814	0.00087767
r3	-0.11248	0.17365	-0.56642	-0.025838	-0.018507
r4	0.010697	-0.38241	-0.69273	-3.0184	0.17717
r5	-0.0020165	-0.14618	-0.51584	-3.0371	-0.99056
r6	-0.00015927	-0.041473	-0.14098	-2.1121	-1.4106

xxx TABLE:mt_x_devi_from_mean xxxxxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5
r1	-6.8892	-5.8892	-6.8892	-5.8892	-5.8892
r2	-4.8892	-2.8892	-4.8892	-2.8892	-3.8892
r3	-1.8892	-0.88919	-0.88919	0.11081	-0.88919
r4	2.1108	2.1108	3.1108	4.1108	2.1108
r5	6.1108	5.1108	5.1108	6.1108	5.1108
r6	8.1108	9.1108	7.1108	9.1108	9.1108

xxx TABLE:mt_x_y_multiply xxxxxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5
r1	-30.237	-76.225	-64.023	-61.882	-29.792
r2	-5.396	-23.242	-4.151	-19.842	0.59004
r3	-14.003	2.3348	-4.4073	-0.40209	-2.4884
r4	7.9905	-12.854	-7.1868	-35.23	9.5287
r5	-18.075	-24.568	-14.271	-53.172	-42.62
r6	-42.83	-87.129	-26.003	-138.66	-121.38

xxx TABLE:mt_y_devi_from_mean xxxxxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5
r1	4.389	12.943	9.2933	10.508	5.0587
r2	1.1037	8.0444	0.84902	6.8677	-0.15171
r3	7.4123	-2.6258	4.9566	-3.6286	2.7985
r4	3.7855	-6.0898	-2.3103	-8.57	4.5142
r5	-2.9579	-4.8071	-2.7924	-8.7013	-8.3392
r6	-5.2806	-9.5633	-3.6568	-15.22	-13.323

f1_cov
-22.0835

f1_cor
-0.8133

4.4.2 Test FF_DISC RAND_VAR MASS2COVCOR Four States-Points

Over some (a,z) states that is 2 by 2, c matrix, and y matrix, find correlation. Positively related.

% Set Parameters

```

mt_c_of_s = [1,2;3,1];
mt_y_of_s = [2,10;5,1.1];
rng(123);
mt_f_of_s = rand(size(mt_c_of_s));
mt_f_of_s = mt_f_of_s/sum(mt_f_of_s, 'all');
bl_display_drvm2covcor = false;
% Call Function
[fl_cov_xy, fl_cor_xy] = ff_disc_rand_var_mass2covcor(... 
    mt_c_of_s, mt_y_of_s, mt_f_of_s, bl_display_drvm2covcor);
display(['cov=' num2str(fl_cov_xy) ',cor=', num2str(fl_cor_xy)]);

cov=1.4446,cor=0.65723

```

Same as before, but now inputs are single column:

```

% Call Function
[fl_cov_xy, fl_cor_xy] = ff_disc_rand_var_mass2covcor(... 
    mt_c_of_s(:), mt_y_of_s(:), mt_f_of_s(:), bl_display_drvm2covcor);
display(['cov=' num2str(fl_cov_xy) ',cor=', num2str(fl_cor_xy)]);

cov=1.4446,cor=0.65723

```

4.4.3 Test FF_DISC RAND VAR MASS2COVCOR Two Random Vectors

Generate two random vectors, with random or even mass, correlation should be zero:

```

% Set Parameters
rng(4567);
mt_c_of_s = rand([20,1])*100;
mt_y_of_s = rand([20,1])*100;
mt_f_of_s = rand(size(mt_c_of_s));
mt_f_of_s = mt_f_of_s/sum(mt_f_of_s, 'all');
bl_display_drvm2covcor = false;
% Call Function
[fl_cov_xy, fl_cor_xy] = ff_disc_rand_var_mass2covcor(... 
    mt_c_of_s, mt_y_of_s, mt_f_of_s, bl_display_drvm2covcor);
display(['cov=' num2str(fl_cov_xy) ',cor=', num2str(fl_cor_xy)]);

cov=-57.6533,cor=-0.062023

```

4.4.4 Test FF_DISC RAND VAR MASS2COVCOR Provide Mean and SD

Same as above, but now provide means and sd for x and y directly. The results are the same as when mean and sd are calculated inside the function.

```

% Set Parameters
rng(4567);
mt_c_of_s = rand([20,1])*100;
mt_y_of_s = rand([20,1])*100;
mt_f_of_s = rand(size(mt_c_of_s));
mt_f_of_s = mt_f_of_s/sum(mt_f_of_s, 'all');
fl_c_mean = sum(mt_f_of_s.*mt_c_of_s);
fl_c_sd = sqrt(sum(mt_f_of_s.*(mt_c_of_s-fl_c_mean).^2));
fl_y_mean = sum(mt_f_of_s.*mt_y_of_s);
fl_y_sd = sqrt(sum(mt_f_of_s.*(mt_y_of_s-fl_y_mean).^2));
bl_display_drvm2covcor = false;
% Call Function
[fl_cov_xy, fl_cor_xy] = ff_disc_rand_var_mass2covcor...

```

```
mt_c_of_s, mt_y_of_s, mt_f_of_s, ...
fl_c_mean, fl_c_sd, ...
fl_y_mean, fl_y_sd, bl_display_drvm2covcor);
display(['cov=' num2str(fl_cov_xy) ',cor=', num2str(fl_cor_xy)]);

cov=-57.6533,cor=-0.062023
```

Chapter 5

Optimizers

5.1 FF_OPTIM_BISEC_SAVEZRONE Derivative Bisection

Go back to [fan's MEconTools Toolbox \(bookdown\)](#), [Matlab Code Examples Repository \(bookdown\)](#), or [Math for Econ with Matlab Repository \(bookdown\)](#).

This is the example vignette for function: `ff_optim_bisec_savezrone` from the [MEconTools Package](#). This functions solves for optimal savings/borrowing level given an anonymous function that provides the derivative of a intertemporal savings problem. The function is solves over a grid of state-space elements that are embeded in the anonymous function. By default, it iterates over 15 iterations with bisection.

The vectorized and looped bisection savings problem rely on this function to solve for optimal savings choices:

- States Grid + Continuous Exact Savings as Share of Cash-on-Hand :[`ff_vfi_az_bisec_loop`](#), high precision even with small grid
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand : [`ff_vfi_az_bisec_vec`](#), precision and speed

5.1.1 Test FF_OPTIM_BISEC_SAVEZRONE Defaults

Call the function with defaults, this solves concurrently for many state-space points' optimization problems:

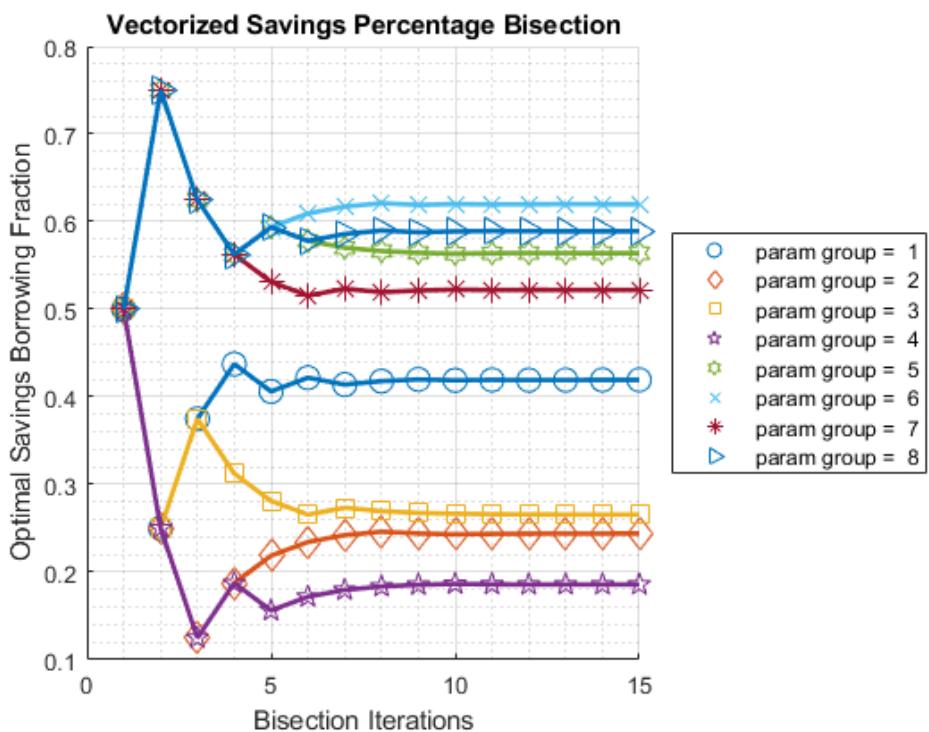
```
ff_optim_bisec_savezrone();
```

Elapsed time is 0.306506 seconds.

BISECT END: iteration=16, norm(ar_mid_fx)=0.00030653

	vartype	paramgroup2	paramgroup3	paramgroup4	paramgroup5
a	"init"	1e-05	1e-05	1e-05	1e-05
b	"init"	0.99999	0.99999	0.99999	0.99999
f_a	"init"	33802	40925	67047	15411
f_b	"init"	-46789	-1.2672e+05	-1.8532e+05	-67518
it1_fp	"fatx"	-0.25973	-1.7159	-2.3655	-1.0421
it1_p	"x"	0.5	0.5	0.5	0.5
it2_fp	"fatx"	0.72822	-0.052631	0.21087	-0.28379
it2_p	"x"	0.25	0.25	0.25	0.25
it3_fp	"fatx"	0.15277	1.8256	-1.1773	0.46124
it3_p	"x"	0.375	0.12501	0.375	0.12501
it4_fp	"fatx"	-0.059183	0.62299	-0.55013	-0.0090579
it4_p	"x"	0.4375	0.18751	0.3125	0.18751

it5_fp	"fatx"	0.044028	0.2488	-0.19454	0.1861
it5_p	"x"	0.40625	0.21876	0.28125	0.15626
it6_fp	"fatx"	-0.0080863	0.090981	0.00054305	0.081339
it6_p	"x"	0.42188	0.23438	0.26563	0.17188
it7_fp	"fatx"	0.017822	0.017593	-0.098707	0.034591
it7_p	"x"	0.41406	0.24219	0.27344	0.17969
it8_fp	"fatx"	0.0048335	-0.017893	-0.049532	0.012405
it8_p	"x"	0.41797	0.2461	0.26954	0.1836
it9_fp	"fatx"	-0.0016347	-0.00024633	-0.02461	0.0015865
it9_p	"x"	0.41992	0.24415	0.26758	0.18555
it10_fp	"fatx"	0.0015973	0.0086488	-0.012063	-0.0037571
it10_p	"x"	0.41895	0.24317	0.26661	0.18653
it11_fp	"fatx"	-1.9235e-05	0.0041952	-0.0057672	-0.0010907
it11_p	"x"	0.41944	0.24366	0.26612	0.18604
it12_fp	"fatx"	0.00078889	0.0019729	-0.0026139	0.00024655
it12_p	"x"	0.41919	0.2439	0.26587	0.1858
it13_fp	"fatx"	0.00038479	0.00086292	-0.0010359	-0.00042242
it13_p	"x"	0.41931	0.24402	0.26575	0.18592
it14_fp	"fatx"	0.00018277	0.0003082	-0.00024654	-8.8022e-05
it14_p	"x"	0.41937	0.24408	0.26569	0.18586
it15_fp	"fatx"	8.1766e-05	3.0909e-05	0.00014822	7.9241e-05
it15_p	"x"	0.4194	0.24412	0.26566	0.18583
it15_level	"level"	0.56205	-0.070025	0.044431	-0.039424
exactSoluSaveborrFrac	"exact"	0.41943	0.24412	0.26567	0.18584
exactSoluSaveborrLevel	"exact"	0.56211	-0.070022	0.044438	-0.039403
exactSoluSaveborrFracGap	"exact"	2.4705e-05	3.402e-06	1.1458e-05	1.4456e-05
exactSoluSaveborrLevelGap	"exact"	5.28e-05	2.6845e-06	6.1825e-06	2.1411e-05



```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx  
CONTAINER NAME: mp_container_map ND Array (Matrix etc)  
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

i	idx	ndim	numel	rowN	colN	sum	mean
---	-----	------	-------	------	------	-----	------

ar_opti_foc_obj	1	1	2	8	1	8	0.00050535	6.3168e-05	9.
ar_opti_save_frac	2	2	2	8	1	8		0.42626	

xxx TABLE:ar_opti_foc_obj xxxxxxxxxxxxxxxxxxxxxxxx								
	c1	c2	c3	c4	c5	c6	c7	c8
	-----	-----	-----	-----	-----	-----	-----	-----
r1	8.1766e-05	3.0909e-05	0.00014822	7.9241e-05	-0.00013343	0.00015981		1.896

xxx TABLE:ar_opti_save_frac xxxxxxxxxxxxxxxxxxxxxxxx								
	c1	c2	c3	c4	c5	c6	c7	c8
	-----	-----	-----	-----	-----	-----	-----	-----
r1	0.4194	0.24412	0.26566	0.18583	0.56406	0.6199	0.522	0.58908

5.1.2 Test FF_OPTIM_BISEC_SAVEZRONE One Individual

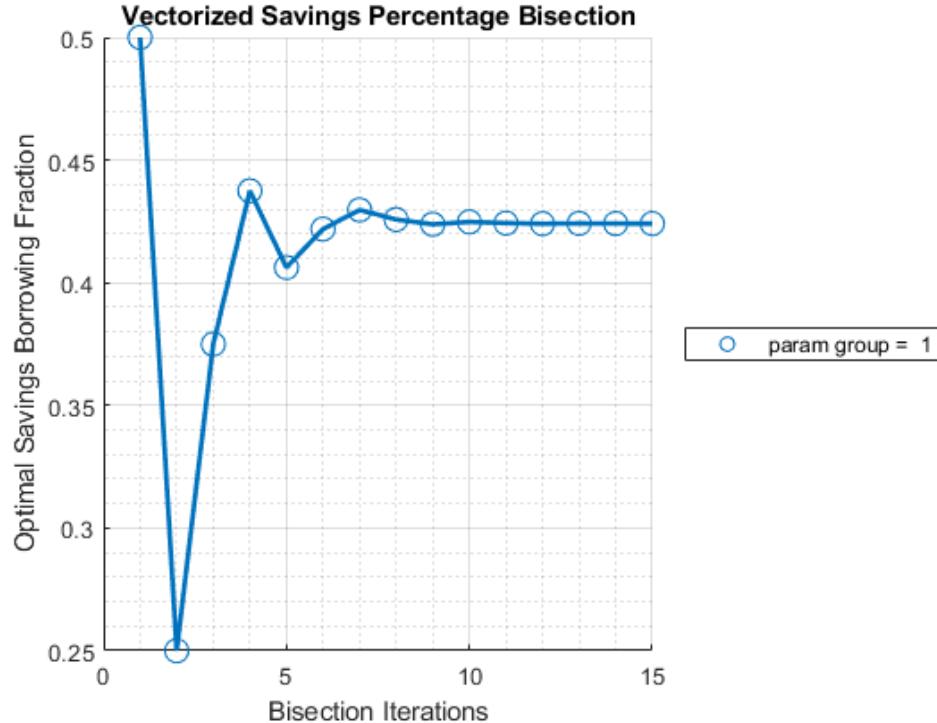
Bisection for savings choice at one state:

```
% Generate the state-space and function
[f1_z1, f1_z2, f1_r, f1_beta] = deal(0.4730, 0.6252, 0.0839, 0.7365);
% ffi_intertemporal_max is a function in ff_optim_bisec_savezrzone for testing
fc_deriv_wth_uniroot = @(x) ffi_intertemporal_max(x, f1_z1, f1_z2, f1_r, f1_beta);
% Call Function
bl_verbose = true;
ff_optim_bisec_savezrzone(fc_deriv_wth_uniroot, bl_verbose);
```

BISECT END: iteration=16, norm(ar_mid_fx)=0.00016724

vartype	paramgroup2
-----	-----
a	"init" 1e-05
b	"init" 0.99999
f_a	"init" 70155
f_b	"init" -95255
it1_fp	"fatx" -0.502
it1_p	"x" 0.5
it2_fp	"fatx" 1.5361
it2_p	"x" 0.25
it3_fp	"fatx" 0.34671
it3_p	"x" 0.375
it4_fp	"fatx" -0.089881
it4_p	"x" 0.4375
it5_fp	"fatx" 0.12259
it5_p	"x" 0.40625
it6_fp	"fatx" 0.015276
it6_p	"x" 0.42188
it7_fp	"fatx" -0.037529
it7_p	"x" 0.42969
it8_fp	"fatx" -0.011188
it8_p	"x" 0.42578
it9_fp	"fatx" 0.0020277
it9_p	"x" 0.42383
it10_fp	"fatx" -0.0045843
it10_p	"x" 0.42481
it11_fp	"fatx" -0.0012793
it11_p	"x" 0.42432
it12_fp	"fatx" 0.00037392

it12_p	"x"	0.42407
it13_fp	"fatx"	-0.00045276
it13_p	"x"	0.4242
it14_fp	"fatx"	-3.9436e-05
it14_p	"x"	0.42413
it15_fp	"fatx"	0.00016724
it15_p	"x"	0.4241
it15_level	"level"	-0.13158



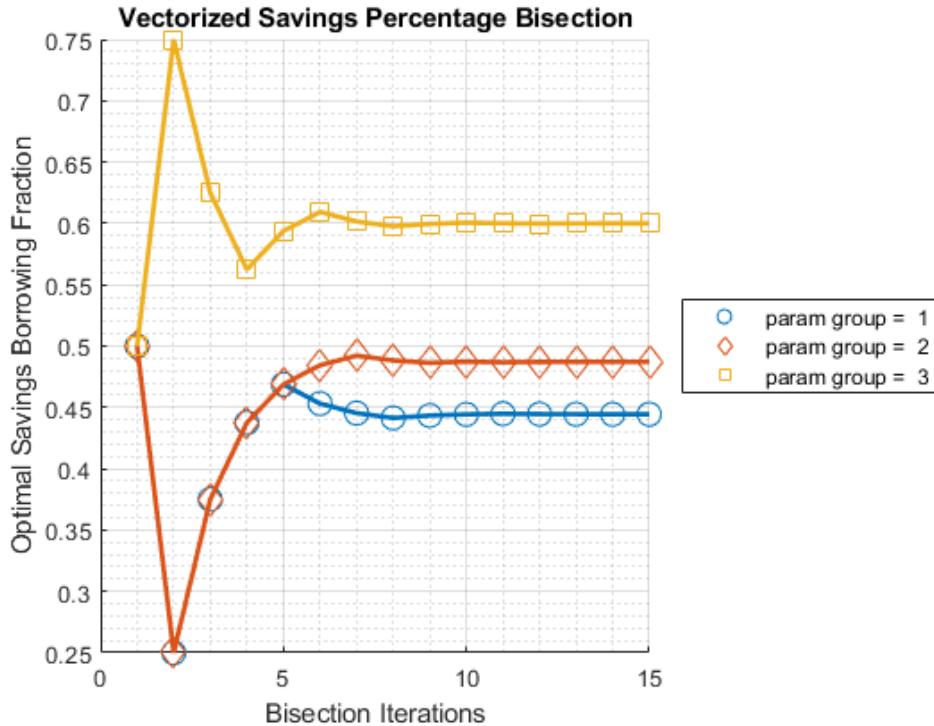
```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      i      idx      value
      -      ---      -----
ar_opti_foc_obj    1       1    0.00016724
ar_opti_save_frac  2       2        0.4241
```

5.1.3 Test FF_OPTIM_BISEC_SAVEZZONE Six Individual States

Solve the two period intertemporal optimization problem with only 6 individual states:

```
% Generate the state-space and function
ar_z1 = [1,2,3]';
ar_z2 = [3,2,1]';
ar_r = [1.05, 1.50, 1.30]';
ar_beta = [0.80, 0.95, 1.50]';
mt_fc_inputs = [ar_z1, ar_z2, ar_r, ar_beta];
% ffi_intertemporal_max is a function in ff_optim_bisec_savezzone for testing
fc_deriv_wth_uniroot = @(x) ffi_intertemporal_max(x, ar_z1, ar_z2, ar_r, ar_beta);
% Call Function
bl_verbose = true;
ff_optim_bisec_savezzone(fc_deriv_wth_uniroot, bl_verbose);
```

BISECT END: iteration=16, norm(ar_mid_fx)=8.9847e-05				
vartype	paramgroup2	paramgroup3	paramgroup4	
-----	-----	-----	-----	-----
a	"init"	1e-05	1e-05	1e-05
b	"init"	0.99999	0.99999	0.99999
f_a	"init"	32475	33928	43671
f_b	"init"	-40594	-35714	-29113
it1_fp	"fatx"	-0.16238	-0.035714	0.29114
it1_p	"x"	0.5	0.5	0.5
it2_fp	"fatx"	0.75773	0.88092	-0.58225
it2_p	"x"	0.25	0.25	0.74999
it3_fp	"fatx"	0.21649	0.33333	-0.077629
it3_p	"x"	0.375	0.375	0.625
it4_fp	"fatx"	0.020615	0.14059	0.11091
it4_p	"x"	0.4375	0.4375	0.5625
it5_fp	"fatx"	-0.07132	0.051539	0.018865
it5_p	"x"	0.46875	0.46875	0.59375
it6_fp	"fatx"	-0.025599	0.0078193	-0.028659
it6_p	"x"	0.45313	0.48438	0.60937
it7_fp	"fatx"	-0.0025711	-0.013955	-0.0047386
it7_p	"x"	0.44531	0.49219	0.60156
it8_fp	"fatx"	0.0090001	-0.0030715	0.0071001
it8_p	"x"	0.44141	0.48828	0.59765
it9_fp	"fatx"	0.0032093	0.0023727	0.0011903
it9_p	"x"	0.44336	0.48633	0.59961
it10_fp	"fatx"	0.00031783	-0.00034971	-0.0017717
it10_p	"x"	0.44434	0.4873	0.60058
it11_fp	"fatx"	-0.0011269	0.0010114	-0.00029011
it11_p	"x"	0.44483	0.48682	0.6001
it12_fp	"fatx"	-0.00040464	0.00033083	0.00045024
it12_p	"x"	0.44458	0.48706	0.59985
it13_fp	"fatx"	-4.3425e-05	-9.4396e-06	8.0103e-05
it13_p	"x"	0.44446	0.48718	0.59997
it14_fp	"fatx"	0.0001372	0.0001607	-0.000105
it14_p	"x"	0.4444	0.48712	0.60003
it15_fp	"fatx"	4.6884e-05	7.5628e-05	-1.2444e-05
it15_p	"x"	0.44443	0.48715	0.6
it15_level	"level"	-0.3686	0.56403	1.6261



```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      i      idx     ndim    numel   rowN   colN      sum      mean
      -      ---     ----   -----   ----   ----   -----   -----
ar_opti_foc_obj    1       1       2       3       1       3  0.00011007 3.6689e-05 4.
ar_opti_save_frac  2       2       2       3       1       3   1.5316  0.51053

xxx TABLE:ar_opti_foc_obj xxxxxxxxxxxxxxxxx
      c1      c2      c3
      -----  -----
r1  4.6884e-05  7.5628e-05 -1.2444e-05

xxx TABLE:ar_opti_save_frac xxxxxxxxxxxxxxxxx
      c1      c2      c3
      -----  -----
r1  0.44443   0.48715   0.6
```

5.1.4 Test FF_OPTIM_BISEC_SAVEZONE Speed

Test Speed doing 6.25 million bisections for a savings problem:

```
% Generate the state-space and function
rng(123);
it_draws = 6250000; % must be even number
ar_z1 = exp(rand([it_draws,1])*3-1.5);
ar_z2 = exp(rand([it_draws,1])*3-1.5);
ar_r = (rand(it_draws,1)*10.0);
ar_beta = [rand(round(it_draws/2),1)*0.9+0.1; rand(round(it_draws/2),1)*0.9+1];
% ffi_intertemporal_max is a function in ff_optim_bisec_savezone for testing
fc_deriv_wth_uniroot = @(x) ffi_intertemporal_max(x, ar_z1, ar_z2, ar_r, ar_beta);
```

```
% Call Function
bl_verbose = false;
bl_timer = true;
[ar_opti_save_frac, ar_opti_save_level] = ff_optim_bisec_savezrone(fc_deriv_wth_uniroot, bl_verbose);

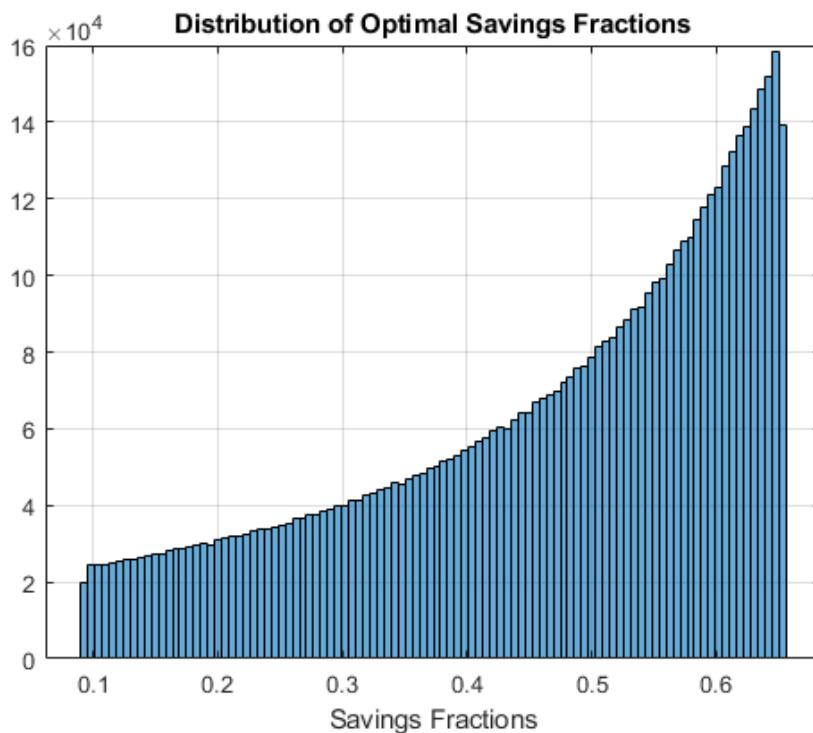
Elapsed time is 4.487754 seconds.

mp_container_map = containers.Map('KeyType','char', 'ValueType','any');
mp_container_map('ar_opti_save_frac') = ar_opti_save_frac;
mp_container_map('ar_opti_save_level') = ar_opti_save_level;
mp_container_map('ar_opti_save_frac_notnan') = ar_opti_save_frac(~isnan(ar_opti_save_frac));
ff_container_map_display(mp_container_map);

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

      i    idx    ndim    numel    rowN    colN    sum    m
      -    ---    ----    -----    -----    ----    ----    --
ar_opti_save_frac      1      1      2    6.25e+06  6.25e+06      1  2.884e+06  0.
ar_opti_save_frac_notnan  2      2      2    6.25e+06  6.25e+06      1  2.884e+06  0.
ar_opti_save_level      3      3      2    6.25e+06  6.25e+06      1  2.9482e+06  0.

figure();
histogram(ar_opti_save_frac(~isnan(ar_opti_save_frac)),100);
title('Distribution of Optimal Savings Fractions');
xlabel('Savings Fractions');
grid on;
```



5.1.5 Define Two Period Intertemporal FOC Log Utility No Shock

See [Household's Utility Maximization Problem and Two-Period Borrowing and Savings Problem given Endowments](#).

```

function [ar_der_i_zero, ar_saveborr_level] = ffi_intertemporal_max(ar_saveborr_frac, z1, z2, r, beta)
    ar_saveborr_level = ar_saveborr_frac.*((z1+z2./(1+r)) - z2./(1+r));
    ar_der_i_zero = 1./((ar_saveborr_level-z1) + (beta.*((r+1))./(z2 + ar_saveborr_level.*((r+1))));
end

```

5.2 FF_OPTIM_MLSEC_SAVEZRONE Derivative Multisection

Go back to [fan's MEconTools Toolbox \(bookdown\)](#), [Matlab Code Examples Repository \(bookdown\)](#), or [Math for Econ with Matlab Repository \(bookdown\)](#).

This is the example vignette for function: [ff_optim_mlsec_savezrone](#) from the [MEconTools Package](#). This functions solves for optimal savings/borrowing level given an anonymous function that provides the derivative of a intertemporal savings problem. This is a vectorized function solved with multi-section (multiple points bisection concurrently).

The vectorized and looped bisection savings problem rely on this function to solve for optimal savings choices:

- States Grid + Continuous Exact Savings as Share of Cash-on-Hand :[ff_vfi_az_bisec_loop](#), high precision even with small grid
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand : [ff_vfi_az_bisec_vec](#), precision and speed

5.2.1 Test FF_OPTIM_MLSEC_SAVEZRONE One Individual

Bisection for savings choice at one state:

```

% Generate the state-space and function
[f1_z1, f1_z2, f1_r, f1_beta] = deal(0.4730, 0.6252, 0.0839, 0.7365);
% ffi_intertemporal_max is a function in ff_optim_mlsec_savezrone for testing
fc_der_i_wth_uniroot = @(x) ffi_intertemporal_max(x, f1_z1, f1_z2, f1_r, f1_beta);
% Call Function
bl_verbose = false;
bl_timer = true;
% optimally borrowing given the parameters here
mp_mlsec_ctrlinfo = containers.Map('KeyType','char', 'ValueType','any');
mp_mlsec_ctrlinfo('it_mzoom_jnt_pnts') = 10;
mp_mlsec_ctrlinfo('it_mzoom_max_iter') = 4;
[f1_opti_save_frac, f1_opti_save_level] = ...
    ff_optim_mlsec_savezrone(fc_der_i_wth_uniroot, bl_verbose, bl_timer, mp_mlsec_ctrlinfo)

Elapsed time is 0.011265 seconds.
f1_opti_save_frac = 0.4241
f1_opti_save_level = -0.1316

```

5.2.2 Test FF_OPTIM_MLSEC_SAVEZRONE 5 Individuals 5 Iterations 5 Points Per Iteration

5 grid points per iteration, and 5 iterations.

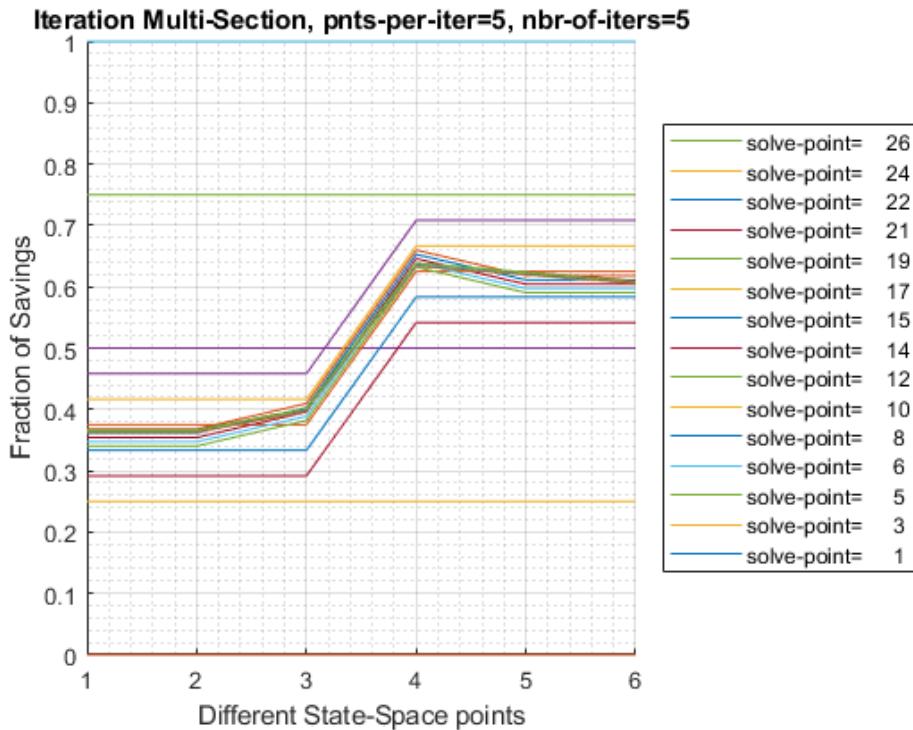
```

% Generate the state-space and function
rng(123);
it_draws = 6; % must be even number
ar_z1 = exp(rand([it_draws,1])*3-1.5);
ar_z2 = exp(rand([it_draws,1])*3-1.5);
ar_r = (rand(it_draws,1)*10.0);
ar_beta = [rand(round(it_draws/2),1)*0.9+0.1; rand(round(it_draws/2),1)*0.9+1];
fc_der_i_wth_uniroot = @(x) ffi_intertemporal_max(x, ar_z1, ar_z2, ar_r, ar_beta);

```

```
% Call Function
bl_verbose = true;
bl_timer = true;
mp_mlsec_ctrlinfo = containers.Map('KeyType','char', 'ValueType','any');
mp_mlsec_ctrlinfo('it_mlsect_jnt_pnts') = 5;
mp_mlsec_ctrlinfo('it_mlsect_max_iter') = 5;
ff_optim_mlsec_savezrone(fc_deriv_wth_uniroot, bl_verbose, bl_timer, mp_mlsec_ctrlinfo);
```

iter	cl_row_names_a	Var1	Var2	Var3	Var4	Var5	Var6
----	-----	-----	-----	-----	-----	-----	-----
0	"point=1"	1e-05	1e-05	1e-05	1e-05	1e-05	1e-05
1	"point=1"	1e-05	1e-05	1e-05	1e-05	1e-05	1e-05
1	"point=2"	0.25001	0.25001	0.25001	0.25001	0.25001	0.25001
1	"point=3"	0.5	0.5	0.5	0.5	0.5	0.5
1	"point=4"	0.75	0.75	0.75	0.75	0.75	0.75
1	"point=5"	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999
2	"point=1"	0.29167	0.29167	0.29167	0.54167	0.54167	0.54167
2	"point=2"	0.33334	0.33334	0.33334	0.58333	0.58333	0.58333
2	"point=3"	0.375	0.375	0.375	0.625	0.625	0.625
2	"point=4"	0.41667	0.41667	0.41667	0.66666	0.66666	0.66666
2	"point=5"	0.45833	0.45833	0.45833	0.70833	0.70833	0.70833
3	"point=1"	0.34028	0.34028	0.38195	0.63194	0.59028	0.59028
3	"point=2"	0.34723	0.34723	0.38889	0.63889	0.59722	0.59722
3	"point=3"	0.35417	0.35417	0.39584	0.64583	0.60416	0.60416
3	"point=4"	0.36111	0.36111	0.40278	0.65277	0.61111	0.61111
3	"point=5"	0.36806	0.36806	0.40972	0.65972	0.61805	0.61805
4	"point=1"	0.36227	0.36227	0.39699	0.6331	0.61921	0.60532
4	"point=2"	0.36343	0.36343	0.39815	0.63426	0.62037	0.60648
4	"point=3"	0.36459	0.36459	0.39931	0.63541	0.62153	0.60764
4	"point=4"	0.36574	0.36574	0.40046	0.63657	0.62268	0.60879
4	"point=5"	0.36669	0.36669	0.40162	0.63773	0.62384	0.60995
5	"point=1"	0.36594	0.36594	0.40066	0.63792	0.62288	0.60783
5	"point=2"	0.36613	0.36613	0.40085	0.63811	0.62307	0.60802
5	"point=3"	0.36632	0.36632	0.40104	0.63831	0.62326	0.60822
5	"point=4"	0.36652	0.36652	0.40124	0.6385	0.62345	0.60841
5	"point=5"	0.36671	0.36671	0.40143	0.63869	0.62365	0.6086



```
Elapsed time is 0.495996 seconds.
```

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean
	-	---	----	-----	----	----	-----	-----
ar_opti_foc_obj	1	1	2	6	6	1	-0.00037648	-6.2746e-05
ar_opti_save_frac	2	2	2	6	6	1	3.0037	0.50061

```
xxx TABLE:ar_opti_foc_obj xxxxxxxxxxxxxxxxx
c1
-----
```

r1	7.0837e-05
r2	-0.0002782
r3	0.00017713
r4	0.00055875
r5	-0.00023392
r6	-0.00067107

```
xxx TABLE:ar_opti_save_frac xxxxxxxxxxxxxxxxx
c1
-----
```

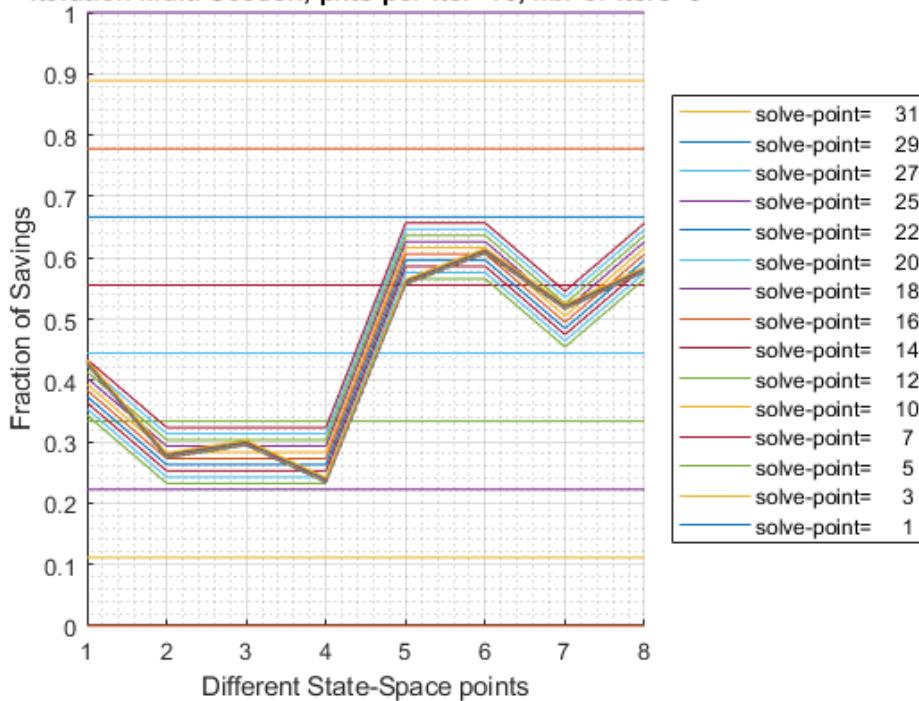
r1	0.36642
r2	0.36661
r3	0.40153
r4	0.63821
r5	0.62297
r6	0.60793

5.2.3 Test FF_OPTIM_MLSEC_SAVEZRONE 8 Individuals 3 Iterations 10 Points Per Iteration

10 grid points per iteration, and 3 iterations.

```
% Generate the state-space and function
rng(123);
it_draws = 8; % must be even number
ar_z1 = exp(rand([it_draws,1])*3-1.5);
ar_z2 = exp(rand([it_draws,1])*3-1.5);
ar_r = (rand(it_draws,1)*10.0);
ar_beta = [rand(round(it_draws/2),1)*0.9+0.1; rand(round(it_draws/2),1)*0.9+1];
fc_deriv_wth_uniroot = @(x) ffi_intertemporal_max(x, ar_z1, ar_z2, ar_r, ar_beta);
% Call Function
bl_verbose = true;
bl_timer = true;
mp_mlsec_ctrlinfo = containers.Map('KeyType','char', 'ValueType','any');
mp_mlsec_ctrlinfo('it_mlsect_jnt_pnts') = 10;
mp_mlsec_ctrlinfo('it_mlsect_max_iter') = 3;
ff_optim_mlsec_savezrone(fc_deriv_wth_uniroot, bl_verbose, bl_timer, mp_mlsec_ctrlinfo);
```

iter	cl_row_names_a	Var1	Var2	Var3	Var4	Var5	Var6	Var
0	"point=1"	1e-05						
1	"point=1"	1e-05						
1	"point=2"	0.11112	0.11112	0.11112	0.11112	0.11112	0.11112	0.11112
1	"point=3"	0.22223	0.22223	0.22223	0.22223	0.22223	0.22223	0.22223
1	"point=4"	0.33334	0.33334	0.33334	0.33334	0.33334	0.33334	0.33334
1	"point=5"	0.44445	0.44445	0.44445	0.44445	0.44445	0.44445	0.44445
1	"point=6"	0.55555	0.55555	0.55555	0.55555	0.55555	0.55555	0.55555
1	"point=7"	0.66666	0.66666	0.66666	0.66666	0.66666	0.66666	0.66666
1	"point=8"	0.77777	0.77777	0.77777	0.77777	0.77777	0.77777	0.77777
1	"point=9"	0.88888	0.88888	0.88888	0.88888	0.88888	0.88888	0.88888
1	"point=10"	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999
2	"point=1"	0.34344	0.23233	0.23233	0.23233	0.56566	0.56566	0.45
2	"point=2"	0.35354	0.24243	0.24243	0.24243	0.57576	0.57576	0.46
2	"point=3"	0.36364	0.25253	0.25253	0.25253	0.58586	0.58586	0.47
2	"point=4"	0.37374	0.26263	0.26263	0.26263	0.59596	0.59596	0.48
2	"point=5"	0.38384	0.27273	0.27273	0.27273	0.60606	0.60606	0.49
2	"point=6"	0.39394	0.28283	0.28283	0.28283	0.61616	0.61616	0.50
2	"point=7"	0.40404	0.29293	0.29293	0.29293	0.62626	0.62626	0.51
2	"point=8"	0.41414	0.30303	0.30303	0.30303	0.63636	0.63636	0.52
2	"point=9"	0.42424	0.31314	0.31314	0.31314	0.64646	0.64646	0.53
2	"point=10"	0.43434	0.32324	0.32324	0.32324	0.65656	0.65656	0.54
3	"point=1"	0.42516	0.27365	0.29385	0.23325	0.55647	0.60698	0.51
3	"point=2"	0.42608	0.27457	0.29477	0.23417	0.55739	0.60789	0.51
3	"point=3"	0.427	0.27549	0.29569	0.23508	0.55831	0.60881	0.51
3	"point=4"	0.42792	0.2764	0.29661	0.236	0.55923	0.60973	0.51
3	"point=5"	0.42884	0.27732	0.29752	0.23692	0.56015	0.61065	0.51
3	"point=6"	0.42975	0.27824	0.29844	0.23784	0.56106	0.61157	0.52
3	"point=7"	0.43067	0.27916	0.29936	0.23876	0.56198	0.61249	0.52
3	"point=8"	0.43159	0.28008	0.30028	0.23967	0.5629	0.6134	0.52
3	"point=9"	0.43251	0.281	0.3012	0.24059	0.56382	0.61432	0.52
3	"point=10"	0.43343	0.28191	0.30212	0.24151	0.56474	0.61524	0.52

Iteration Multi-Section, pnts-per-iter=10, nbr-of-iters=3

```
Elapsed time is 0.486844 seconds.
```

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean
-	-	---	----	-----	----	----	-----	-----
ar_opti_foc_obj	1	1	2	8	8	1	0.0033175	0.00041468
ar_opti_save_frac	2	2	2	8	8	1	3.5124	0.43905

```
xxx TABLE:ar_opti_foc_obj xxxxxxxxxxxxxxxxx
c1
```

```
r1      0.00087102
r2      0.0033354
r3      -0.0044871
r4      0.001317
r5      -0.0017862
r6      0.0050249
r7      -0.00058496
r8      -0.00037273
```

```
xxx TABLE:ar_opti_save_frac xxxxxxxxxxxxxxxxx
c1
```

```
r1      0.42838
r2      0.28054
r3      0.2989
r4      0.23371
r5      0.55877
r6      0.61019
```

```
r7      0.5202
r8      0.58172
```

5.2.4 Test FF_OPTIM_MLSEC_SAVEZRONE Speed

Test Speed doing 6.25 million multisections for a savings problem:

```
% Generate the state-space and function
rng(123);
it_draws = 6250000; % must be even number
ar_z1 = exp(rand([it_draws,1])*3-1.5);
ar_z2 = exp(rand([it_draws,1])*3-1.5);
ar_r = (rand(it_draws,1)*10.0);
ar_beta = [rand(round(it_draws/2),1)*0.9+0.1; rand(round(it_draws/2),1)*0.9+1];
% ffi_intertemporal_max is a function in ff_optim_mlsec_savezrone for testing
fc_deriv_wth_uniroot = @(x) ffi_intertemporal_max(x, ar_z1, ar_z2, ar_r, ar_beta);
% Call Function
bl_verbose = false;
bl_timer = true;
[ar_opti_save_frac, ar_opti_save_level] = ff_optim_mlsec_savezrone(fc_deriv_wth_uniroot, bl_verbose);

Elapsed time is 16.390434 seconds.

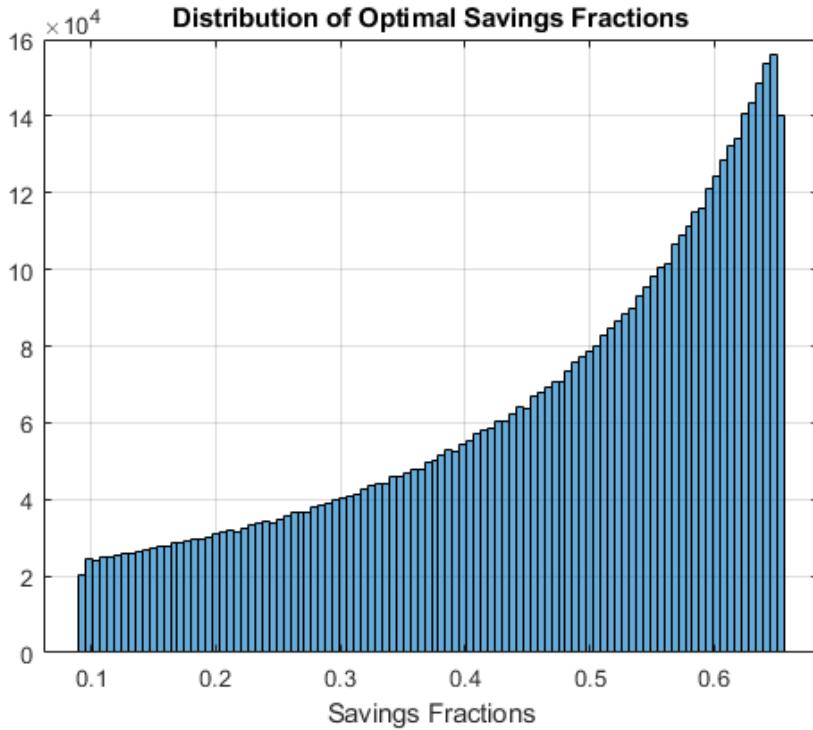
mp_container_map = containers.Map('KeyType','char', 'ValueType','any');
mp_container_map('ar_opti_save_frac') = ar_opti_save_frac;
mp_container_map('ar_opti_save_level') = ar_opti_save_level;
mp_container_map('ar_opti_save_frac_notnan') = ar_opti_save_frac(~isnan(ar_opti_save_frac));
ff_container_map_display(mp_container_map);

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

```

i	idx	ndim	numel	rowN	colN	sum	m	
-	---	----	-----	-----	----	-----	---	
ar_opti_save_frac	1	1	2	6.25e+06	6.25e+06	1	2.884e+06	0.
ar_opti_save_frac_notnan	2	2	2	6.25e+06	6.25e+06	1	2.884e+06	0.
ar_opti_save_level	3	3	2	6.25e+06	6.25e+06	1	2.9482e+06	0.

```
figure();
histogram(ar_opti_save_frac(~isnan(ar_opti_save_frac)),100);
title('Distribution of Optimal Savings Fractions');
xlabel('Savings Fractions');
grid on;
```



5.2.5 Define Two Period Intertemporal FOC Log Utility No Shock

See [Household's Utility Maximization Problem and Two-Period Borrowing and Savings Problem given Endowments](#).

```
function [ar_der_i_zero, ar_saveborr_level] = ffi_intertemporal_max(ar_saveborr_frac, z1, z2, r, beta)
    ar_saveborr_level = ar_saveborr_frac.*((z1+z2)/(1+r)) - z2/(1+r);
    ar_der_i_zero = 1./((ar_saveborr_level-z1) + (beta.*((r+1))./(z2 + ar_saveborr_level.*((r+1))));
end
```

5.3 FF_OPTIM_MZOOM_SAVEZONE Derivative Multi-section

Go back to [fan's MEconTools Toolbox \(bookdown\)](#), [Matlab Code Examples Repository \(bookdown\)](#), or [Math for Econ with Matlab Repository \(bookdown\)](#).

This is the example vignette for function: `ff_optim_mzoom_savezone` from the [MEconTools Package](#). This functions solves for optimal savings/borrowing level given an anonymous function that provides the utility (not derivative) of a intertemporal savings problem. This is a vectorized function solves for multiple state-space elements at the same time. The function allows for controls of iteration counts, the number of evaluations per iteration, and how much to "zoom-in" for each iteration around the last iteration's maximum/optimal choice.

Note that if first order conditions are available this method should not be used, but `ff_optim_mlsec_savezone` should be used. `ff_optim_mlsec_savezone` relies on bisection. In the first example below more values are needed to achieve the same precision than under `ff_optim_mlsec_savezone`. However, increasing might not expensive given vectorization, should increase time cost linearly in generally. MZOOM is much more robust than bisection based methods. And by increasing the number of points evaluated per iteration, in limited number of iterations, the approximately exact optimal savings choice can be found.

The vectorized zooming savings problem rely on this function to solve for optimal savings choices:

- States Grid + Approximate Continuous Exact Savings (zoom) as Share of Cash-on-Hand : `ff_vfi_az_zoom_vec`, precision and speed

5.3.1 Test FF_OPTIM_MZOOM_SAVEZRONE One Individual

Bisection for savings choice at one state:

```
% Generate the state-space and function
[fl_z1, fl_z2, fl_r, fl_beta] = deal(0.4730, 0.6252, 0.0839, 0.7365);
% ffi_intertemporal_max is a function in ff_optim_mlsec_savezrzone for testing
fc_util = @(x) ffi_intertemporal_util(x, fl_z1, fl_z2, fl_r, fl_beta);
% Call Function
bl_verbose = false;
bl_timer = true;
% optimally borrowing given the parameters here
mp_mzoom_ctrlinfo = containers.Map('KeyType','char', 'ValueType','any');
mp_mzoom_ctrlinfo('it_mzoom_jnt_pnts') = 15;
mp_mzoom_ctrlinfo('it_mzoom_max_iter') = 10;
mp_mzoom_ctrlinfo('it_mzoom_zm_ratio') = 0.25;
[fl_opti_save_frac, fl_opti_save_level] = ...
    ff_optim_mzoom_savezrzone(fc_util, bl_verbose, bl_timer, mp_mzoom_ctrlinfo)
```

Elapsed time is 0.011586 seconds.

```
fl_opti_save_frac = 0.4241
fl_opti_save_level = -0.1316
```

5.3.2 Test FF_OPTIM_MZOOM_SAVEZRONE 4 Individuals 3 Iterations 50 Points Per Iteration

5 grid points per iteration, and 5 iterations.

```
% Generate the state-space and function
rng(123);
it_draws = 4; % must be even number
ar_z1 = exp(rand([it_draws,1])*3-1.5);
ar_z2 = exp(rand([it_draws,1])*3-1.5);
ar_r = (rand(it_draws,1)*10.0);
ar_beta = [rand(round(it_draws/2),1)*0.9+0.1; rand(round(it_draws/2),1)*0.9+1];
fc_util = @(x) ffi_intertemporal_util(x, ar_z1, ar_z2, ar_r, ar_beta);
% Call Function
bl_verbose = true;
bl_timer = true;
mp_mzoom_ctrlinfo = containers.Map('KeyType','char', 'ValueType','any');
mp_mzoom_ctrlinfo('it_mzoom_jnt_pnts') = 50;
mp_mzoom_ctrlinfo('it_mzoom_max_iter') = 3;
mp_mzoom_ctrlinfo('it_mzoom_zm_ratio') = 0;
[fl_opti_save_frac, fl_opti_save_level] = ...
    ff_optim_mzoom_savezrzone(fc_util, bl_verbose, bl_timer, mp_mzoom_ctrlinfo);
```

iter	cl_row_names_a	Var1	Var2	Var3	Var4
---	-----	-----	-----	-----	-----
1	"point=1"	1e-05	1e-05	1e-05	1e-05
1	"point=2"	0.020418	0.020418	0.020418	0.020418
1	"point=3"	0.040826	0.040826	0.040826	0.040826
1	"point=4"	0.061233	0.061233	0.061233	0.061233
1	"point=5"	0.081641	0.081641	0.081641	0.081641
1	"point=6"	0.10205	0.10205	0.10205	0.10205
1	"point=7"	0.12246	0.12246	0.12246	0.12246
1	"point=8"	0.14286	0.14286	0.14286	0.14286
1	"point=9"	0.16327	0.16327	0.16327	0.16327
1	"point=10"	0.18368	0.18368	0.18368	0.18368
1	"point=11"	0.20409	0.20409	0.20409	0.20409

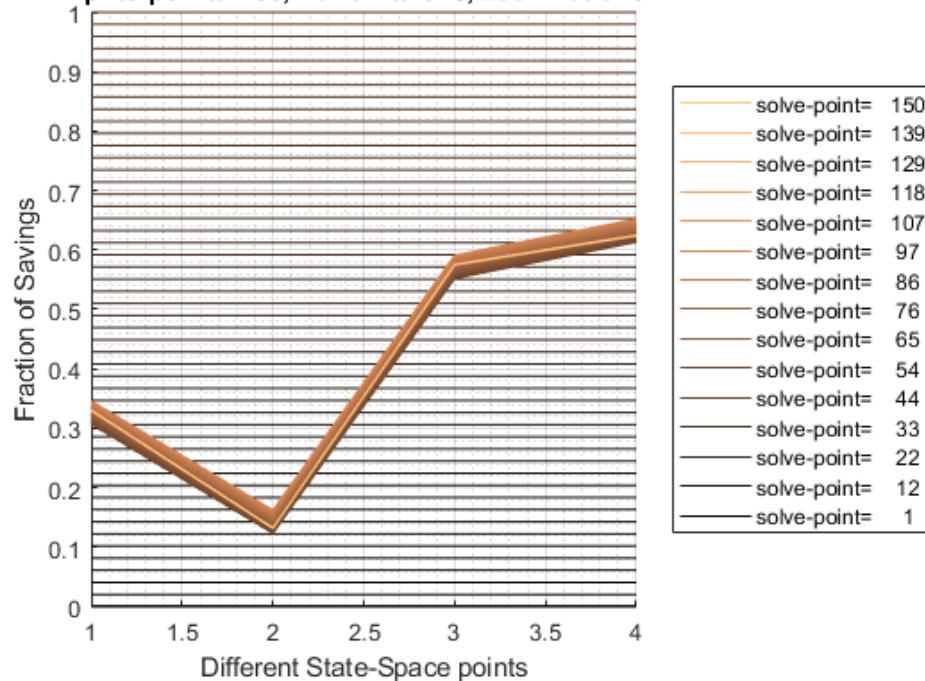
1	"point=12"	0.2245	0.2245	0.2245	0.2245
1	"point=13"	0.2449	0.2449	0.2449	0.2449
1	"point=14"	0.26531	0.26531	0.26531	0.26531
1	"point=15"	0.28572	0.28572	0.28572	0.28572
1	"point=16"	0.30613	0.30613	0.30613	0.30613
1	"point=17"	0.32653	0.32653	0.32653	0.32653
1	"point=18"	0.34694	0.34694	0.34694	0.34694
1	"point=19"	0.36735	0.36735	0.36735	0.36735
1	"point=20"	0.38776	0.38776	0.38776	0.38776
1	"point=21"	0.40817	0.40817	0.40817	0.40817
1	"point=22"	0.42857	0.42857	0.42857	0.42857
1	"point=23"	0.44898	0.44898	0.44898	0.44898
1	"point=24"	0.46939	0.46939	0.46939	0.46939
1	"point=25"	0.4898	0.4898	0.4898	0.4898
1	"point=26"	0.5102	0.5102	0.5102	0.5102
1	"point=27"	0.53061	0.53061	0.53061	0.53061
1	"point=28"	0.55102	0.55102	0.55102	0.55102
1	"point=29"	0.57143	0.57143	0.57143	0.57143
1	"point=30"	0.59183	0.59183	0.59183	0.59183
1	"point=31"	0.61224	0.61224	0.61224	0.61224
1	"point=32"	0.63265	0.63265	0.63265	0.63265
1	"point=33"	0.65306	0.65306	0.65306	0.65306
1	"point=34"	0.67347	0.67347	0.67347	0.67347
1	"point=35"	0.69387	0.69387	0.69387	0.69387
1	"point=36"	0.71428	0.71428	0.71428	0.71428
1	"point=37"	0.73469	0.73469	0.73469	0.73469
1	"point=38"	0.7551	0.7551	0.7551	0.7551
1	"point=39"	0.7755	0.7755	0.7755	0.7755
1	"point=40"	0.79591	0.79591	0.79591	0.79591
1	"point=41"	0.81632	0.81632	0.81632	0.81632
1	"point=42"	0.83673	0.83673	0.83673	0.83673
1	"point=43"	0.85714	0.85714	0.85714	0.85714
1	"point=44"	0.87754	0.87754	0.87754	0.87754
1	"point=45"	0.89795	0.89795	0.89795	0.89795
1	"point=46"	0.91836	0.91836	0.91836	0.91836
1	"point=47"	0.93877	0.93877	0.93877	0.93877
1	"point=48"	0.95917	0.95917	0.95917	0.95917
1	"point=49"	0.97958	0.97958	0.97958	0.97958
1	"point=50"	0.99999	0.99999	0.99999	0.99999
2	"point=1"	0.30693	0.12326	0.55182	0.61304
2	"point=2"	0.30773	0.12406	0.55262	0.61384
2	"point=3"	0.30853	0.12486	0.55342	0.61464
2	"point=4"	0.30933	0.12566	0.55422	0.61544
2	"point=5"	0.31013	0.12646	0.55502	0.61624
2	"point=6"	0.31093	0.12726	0.55582	0.61704
2	"point=7"	0.31173	0.12806	0.55662	0.61784
2	"point=8"	0.31253	0.12886	0.55742	0.61865
2	"point=9"	0.31333	0.12966	0.55822	0.61945
2	"point=10"	0.31413	0.13046	0.55902	0.62025
2	"point=11"	0.31493	0.13126	0.55982	0.62105
2	"point=12"	0.31573	0.13206	0.56062	0.62185
2	"point=13"	0.31653	0.13286	0.56142	0.62265
2	"point=14"	0.31733	0.13366	0.56222	0.62345
2	"point=15"	0.31813	0.13446	0.56302	0.62425
2	"point=16"	0.31893	0.13526	0.56382	0.62505
2	"point=17"	0.31973	0.13606	0.56462	0.62585
2	"point=18"	0.32053	0.13686	0.56542	0.62665
2	"point=19"	0.32133	0.13766	0.56623	0.62745

2	"point=20"	0.32213	0.13846	0.56703	0.62825
2	"point=21"	0.32293	0.13926	0.56783	0.62905
2	"point=22"	0.32373	0.14006	0.56863	0.62985
2	"point=23"	0.32453	0.14086	0.56943	0.63065
2	"point=24"	0.32533	0.14166	0.57023	0.63145
2	"point=25"	0.32613	0.14246	0.57103	0.63225
2	"point=26"	0.32693	0.14326	0.57183	0.63305
2	"point=27"	0.32773	0.14406	0.57263	0.63385
2	"point=28"	0.32853	0.14487	0.57343	0.63465
2	"point=29"	0.32934	0.14567	0.57423	0.63545
2	"point=30"	0.33014	0.14647	0.57503	0.63625
2	"point=31"	0.33094	0.14727	0.57583	0.63705
2	"point=32"	0.33174	0.14807	0.57663	0.63785
2	"point=33"	0.33254	0.14887	0.57743	0.63865
2	"point=34"	0.33334	0.14967	0.57823	0.63945
2	"point=35"	0.33414	0.15047	0.57903	0.64025
2	"point=36"	0.33494	0.15127	0.57983	0.64105
2	"point=37"	0.33574	0.15207	0.58063	0.64185
2	"point=38"	0.33654	0.15287	0.58143	0.64265
2	"point=39"	0.33734	0.15367	0.58223	0.64345
2	"point=40"	0.33814	0.15447	0.58303	0.64425
2	"point=41"	0.33894	0.15527	0.58383	0.64506
2	"point=42"	0.33974	0.15607	0.58463	0.64586
2	"point=43"	0.34054	0.15687	0.58543	0.64666
2	"point=44"	0.34134	0.15767	0.58623	0.64746
2	"point=45"	0.34214	0.15847	0.58703	0.64826
2	"point=46"	0.34294	0.15927	0.58783	0.64906
2	"point=47"	0.34374	0.16007	0.58863	0.64986
2	"point=48"	0.34454	0.16087	0.58943	0.65066
2	"point=49"	0.34534	0.16167	0.59023	0.65146
2	"point=50"	0.34614	0.16247	0.59103	0.65226
3	"point=1"	0.32937	0.13129	0.57426	0.62348
3	"point=2"	0.3294	0.13132	0.57429	0.62351
3	"point=3"	0.32943	0.13135	0.57432	0.62354
3	"point=4"	0.32946	0.13139	0.57435	0.62357
3	"point=5"	0.32949	0.13142	0.57439	0.6236
3	"point=6"	0.32952	0.13145	0.57442	0.62364
3	"point=7"	0.32955	0.13148	0.57445	0.62367
3	"point=8"	0.32959	0.13151	0.57448	0.6237
3	"point=9"	0.32962	0.13154	0.57451	0.62373
3	"point=10"	0.32965	0.13157	0.57454	0.62376
3	"point=11"	0.32968	0.13161	0.57457	0.62379
3	"point=12"	0.32971	0.13164	0.5746	0.62382
3	"point=13"	0.32974	0.13167	0.57464	0.62385
3	"point=14"	0.32977	0.1317	0.57467	0.62389
3	"point=15"	0.32981	0.13173	0.5747	0.62392
3	"point=16"	0.32984	0.13176	0.57473	0.62395
3	"point=17"	0.32987	0.13179	0.57476	0.62398
3	"point=18"	0.3299	0.13182	0.57479	0.62401
3	"point=19"	0.32993	0.13186	0.57482	0.62404
3	"point=20"	0.32996	0.13189	0.57486	0.62407
3	"point=21"	0.32999	0.13192	0.57489	0.62411
3	"point=22"	0.33003	0.13195	0.57492	0.62414
3	"point=23"	0.33006	0.13198	0.57495	0.62417
3	"point=24"	0.33009	0.13201	0.57498	0.6242
3	"point=25"	0.33012	0.13204	0.57501	0.62423
3	"point=26"	0.33015	0.13208	0.57504	0.62426
3	"point=27"	0.33018	0.13211	0.57508	0.62429

3	"point=28"	0.33021	0.13214	0.57511	0.62433
3	"point=29"	0.33025	0.13217	0.57514	0.62436
3	"point=30"	0.33028	0.1322	0.57517	0.62439
3	"point=31"	0.33031	0.13223	0.5752	0.62442
3	"point=32"	0.33034	0.13226	0.57523	0.62445
3	"point=33"	0.33037	0.1323	0.57526	0.62448
3	"point=34"	0.3304	0.13233	0.5753	0.62451
3	"point=35"	0.33043	0.13236	0.57533	0.62455
3	"point=36"	0.33046	0.13239	0.57536	0.62458
3	"point=37"	0.3305	0.13242	0.57539	0.62461
3	"point=38"	0.33053	0.13245	0.57542	0.62464
3	"point=39"	0.33056	0.13248	0.57545	0.62467
3	"point=40"	0.33059	0.13252	0.57548	0.6247
3	"point=41"	0.33062	0.13255	0.57551	0.62473
3	"point=42"	0.33065	0.13258	0.57555	0.62477
3	"point=43"	0.33068	0.13261	0.57558	0.6248
3	"point=44"	0.33072	0.13264	0.57561	0.62483
3	"point=45"	0.33075	0.13267	0.57564	0.62486
3	"point=46"	0.33078	0.1327	0.57567	0.62489
3	"point=47"	0.33081	0.13273	0.5757	0.62492
3	"point=48"	0.33084	0.13277	0.57573	0.62495
3	"point=49"	0.33087	0.1328	0.57577	0.62498
3	"point=50"	0.3309	0.13283	0.5758	0.62502

Vectorized Exact Zooming Optimization, Savings Fractions

pnts-per-iter=50, nbr-of-iters=3, zoom-ratio=0



iter	cl_row_names_a	Var1	Var2	Var3	Var4
---	-----	-----	-----	-----	-----
1	"point=1"	-3.6912	-1.9565	-12.83	-14.789
1	"point=2"	0.058694	-0.80561	-2.4984	-2.1254
1	"point=3"	0.38043	-0.72015	-1.5784	-0.99337
1	"point=4"	0.55947	-0.67935	-1.0493	-0.34024
1	"point=5"	0.67979	-0.65711	-0.68055	0.11647
1	"point=6"	0.7677	-0.64529	-0.39997	0.46531
1	"point=7"	0.8349	-0.64026	-0.17534	0.74571

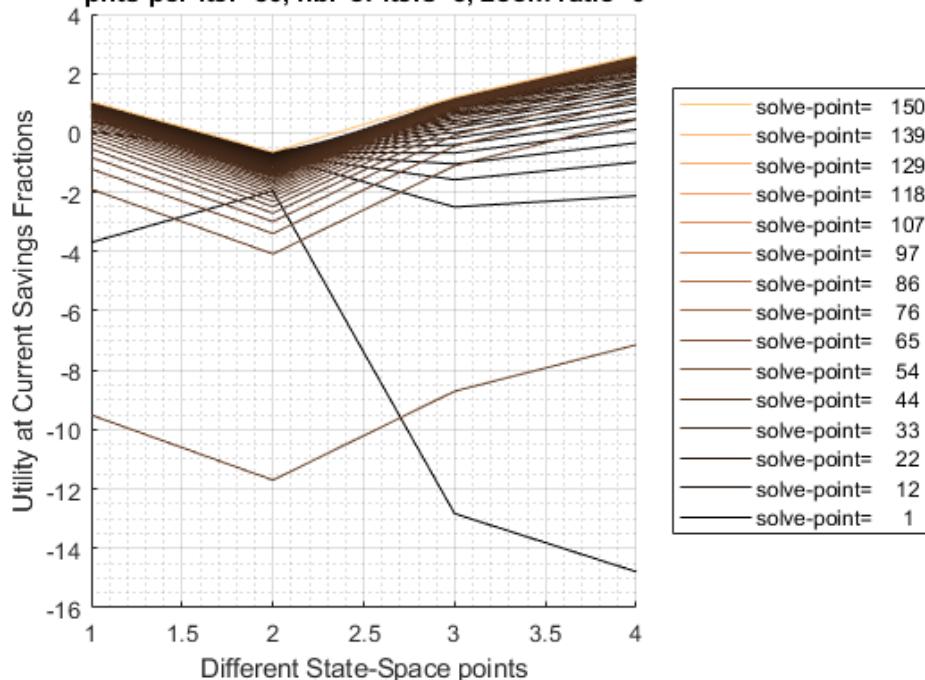
1	"point=8"	0.88763	-0.6401	0.010483	0.9787
1	"point=9"	0.92959	-0.64367	0.16774	1.1768
1	"point=10"	0.96316	-0.65026	0.30302	1.3481
1	"point=11"	0.98996	-0.65938	0.4208	1.4981
1	"point=12"	1.0111	-0.67071	0.52427	1.6308
1	"point=13"	1.0275	-0.684	0.61578	1.7489
1	"point=14"	1.0397	-0.6991	0.69709	1.8547
1	"point=15"	1.0482	-0.71588	0.76958	1.9499
1	"point=16"	1.0533	-0.73426	0.83429	2.0357
1	"point=17"	1.0554	-0.75419	0.8921	2.1132
1	"point=18"	1.0546	-0.77564	0.94367	2.1833
1	"point=19"	1.0512	-0.79861	0.98955	2.2467
1	"point=20"	1.0451	-0.82309	1.0302	2.3039
1	"point=21"	1.0366	-0.8491	1.066	2.3554
1	"point=22"	1.0256	-0.87669	1.0971	2.4015
1	"point=23"	1.0123	-0.90591	1.124	2.4425
1	"point=24"	0.99654	-0.93682	1.1466	2.4788
1	"point=25"	0.97838	-0.9695	1.1652	2.5104
1	"point=26"	0.95775	-1.004	1.1798	2.5375
1	"point=27"	0.93459	-1.0406	1.1905	2.5602
1	"point=28"	0.90881	-1.0792	1.1973	2.5785
1	"point=29"	0.88029	-1.1202	1.2002	2.5925
1	"point=30"	0.84886	-1.1635	1.1991	2.6022
1	"point=31"	0.81434	-1.2096	1.1938	2.6073
1	"point=32"	0.77649	-1.2587	1.1843	2.6078
1	"point=33"	0.73504	-1.3109	1.1703	2.6035
1	"point=34"	0.68964	-1.3668	1.1514	2.594
1	"point=35"	0.63987	-1.4268	1.1274	2.5792
1	"point=36"	0.58522	-1.4913	1.0978	2.5584
1	"point=37"	0.52505	-1.5611	1.062	2.5312
1	"point=38"	0.45857	-1.6369	1.0192	2.4968
1	"point=39"	0.38475	-1.7198	0.96837	2.4541
1	"point=40"	0.3023	-1.8111	0.90834	2.4021
1	"point=41"	0.20947	-1.9126	0.83737	2.3388
1	"point=42"	0.10391	-2.0266	0.75313	2.2622
1	"point=43"	-0.017693	-2.1564	0.65234	2.1687
1	"point=44"	-0.16019	-2.3069	0.53016	2.0538
1	"point=45"	-0.33112	-2.4857	0.37908	1.9097
1	"point=46"	-0.54312	-2.7054	0.18649	1.724
1	"point=47"	-0.81989	-2.9896	-0.071303	1.4729
1	"point=48"	-1.2146	-3.3917	-0.44748	1.1033
1	"point=49"	-1.8971	-4.0814	-1.1118	0.44547
1	"point=50"	-9.5085	-11.7	-8.7054	-7.1418
2	"point=1"	1.0535	-0.64017	1.1975	2.6074
2	"point=2"	1.0536	-0.64009	1.1977	2.6075
2	"point=3"	1.0537	-0.64001	1.1979	2.6076
2	"point=4"	1.0539	-0.63995	1.198	2.6077
2	"point=5"	1.054	-0.63989	1.1982	2.6077
2	"point=6"	1.0541	-0.63983	1.1984	2.6078
2	"point=7"	1.0542	-0.63979	1.1985	2.6079
2	"point=8"	1.0543	-0.63975	1.1986	2.6079
2	"point=9"	1.0544	-0.63971	1.1988	2.608
2	"point=10"	1.0545	-0.63969	1.1989	2.608
2	"point=11"	1.0546	-0.63967	1.199	2.6081
2	"point=12"	1.0547	-0.63966	1.1992	2.6081
2	"point=13"	1.0548	-0.63965	1.1993	2.6081
2	"point=14"	1.0548	-0.63965	1.1994	2.6081
2	"point=15"	1.0549	-0.63966	1.1995	2.6081

2	"point=16"	1.055	-0.63967	1.1996	2.6081
2	"point=17"	1.0551	-0.63969	1.1997	2.6081
2	"point=18"	1.0551	-0.63971	1.1998	2.6081
2	"point=19"	1.0552	-0.63975	1.1998	2.6081
2	"point=20"	1.0552	-0.63978	1.1999	2.6081
2	"point=21"	1.0553	-0.63983	1.2	2.608
2	"point=22"	1.0553	-0.63988	1.2	2.608
2	"point=23"	1.0553	-0.63993	1.2001	2.6079
2	"point=24"	1.0554	-0.63999	1.2001	2.6079
2	"point=25"	1.0554	-0.64006	1.2002	2.6078
2	"point=26"	1.0554	-0.64013	1.2002	2.6077
2	"point=27"	1.0555	-0.64021	1.2002	2.6077
2	"point=28"	1.0555	-0.64029	1.2003	2.6076
2	"point=29"	1.0555	-0.64038	1.2003	2.6075
2	"point=30"	1.0555	-0.64048	1.2003	2.6074
2	"point=31"	1.0555	-0.64058	1.2003	2.6073
2	"point=32"	1.0555	-0.64069	1.2003	2.6071
2	"point=33"	1.0555	-0.6408	1.2003	2.607
2	"point=34"	1.0555	-0.64091	1.2003	2.6069
2	"point=35"	1.0555	-0.64104	1.2002	2.6067
2	"point=36"	1.0554	-0.64116	1.2002	2.6066
2	"point=37"	1.0554	-0.64129	1.2002	2.6064
2	"point=38"	1.0554	-0.64143	1.2001	2.6063
2	"point=39"	1.0554	-0.64157	1.2001	2.6061
2	"point=40"	1.0553	-0.64172	1.2001	2.6059
2	"point=41"	1.0553	-0.64188	1.2	2.6057
2	"point=42"	1.0552	-0.64203	1.1999	2.6056
2	"point=43"	1.0552	-0.6422	1.1999	2.6053
2	"point=44"	1.0551	-0.64236	1.1998	2.6051
2	"point=45"	1.0551	-0.64254	1.1997	2.6049
2	"point=46"	1.055	-0.64271	1.1996	2.6047
2	"point=47"	1.0549	-0.64289	1.1995	2.6045
2	"point=48"	1.0549	-0.64308	1.1994	2.6042
2	"point=49"	1.0548	-0.64327	1.1993	2.604
2	"point=50"	1.0547	-0.64347	1.1992	2.6037
3	"point=1"	1.0555	-0.63967	1.2003	2.6081
3	"point=2"	1.0555	-0.63967	1.2003	2.6081
3	"point=3"	1.0555	-0.63967	1.2003	2.6081
3	"point=4"	1.0555	-0.63967	1.2003	2.6081
3	"point=5"	1.0555	-0.63967	1.2003	2.6081
3	"point=6"	1.0555	-0.63967	1.2003	2.6081
3	"point=7"	1.0555	-0.63967	1.2003	2.6081
3	"point=8"	1.0555	-0.63966	1.2003	2.6081
3	"point=9"	1.0555	-0.63966	1.2003	2.6081
3	"point=10"	1.0555	-0.63966	1.2003	2.6081
3	"point=11"	1.0555	-0.63966	1.2003	2.6081
3	"point=12"	1.0555	-0.63966	1.2003	2.6081
3	"point=13"	1.0555	-0.63966	1.2003	2.6081
3	"point=14"	1.0555	-0.63966	1.2003	2.6081
3	"point=15"	1.0555	-0.63966	1.2003	2.6081
3	"point=16"	1.0555	-0.63966	1.2003	2.6081
3	"point=17"	1.0555	-0.63966	1.2003	2.6081
3	"point=18"	1.0555	-0.63966	1.2003	2.6081
3	"point=19"	1.0555	-0.63966	1.2003	2.6081
3	"point=20"	1.0555	-0.63966	1.2003	2.6081
3	"point=21"	1.0555	-0.63966	1.2003	2.6081
3	"point=22"	1.0555	-0.63966	1.2003	2.6081
3	"point=23"	1.0555	-0.63966	1.2003	2.6081

3	"point=24"	1.0555	-0.63966	1.2003	2.6081
3	"point=25"	1.0555	-0.63966	1.2003	2.6081
3	"point=26"	1.0555	-0.63966	1.2003	2.6081
3	"point=27"	1.0555	-0.63966	1.2003	2.6081
3	"point=28"	1.0555	-0.63966	1.2003	2.6081
3	"point=29"	1.0555	-0.63966	1.2003	2.6081
3	"point=30"	1.0555	-0.63966	1.2003	2.6081
3	"point=31"	1.0555	-0.63965	1.2003	2.6081
3	"point=32"	1.0555	-0.63965	1.2003	2.6081
3	"point=33"	1.0555	-0.63965	1.2003	2.6081
3	"point=34"	1.0555	-0.63965	1.2003	2.6081
3	"point=35"	1.0555	-0.63965	1.2003	2.6081
3	"point=36"	1.0555	-0.63965	1.2003	2.6081
3	"point=37"	1.0555	-0.63965	1.2003	2.6081
3	"point=38"	1.0555	-0.63965	1.2003	2.6081
3	"point=39"	1.0555	-0.63965	1.2003	2.6081
3	"point=40"	1.0555	-0.63965	1.2003	2.6081
3	"point=41"	1.0555	-0.63965	1.2003	2.6081
3	"point=42"	1.0555	-0.63965	1.2003	2.6081
3	"point=43"	1.0555	-0.63965	1.2003	2.6081
3	"point=44"	1.0555	-0.63965	1.2003	2.6081
3	"point=45"	1.0555	-0.63965	1.2003	2.6081
3	"point=46"	1.0555	-0.63965	1.2003	2.6081
3	"point=47"	1.0555	-0.63965	1.2003	2.6081
3	"point=48"	1.0555	-0.63965	1.2003	2.6081
3	"point=49"	1.0555	-0.63965	1.2003	2.6081
3	"point=50"	1.0555	-0.63965	1.2003	2.6081

Vectorized Exact Zooming Optimization, U(save)

pnts-per-iter=50, nbr-of-iters=3, zoom-ratio=0



Elapsed time is 1.304303 seconds.

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

i	idx	ndim	numel	rowN	colN	sum	mean	std
---	-----	------	-------	------	------	-----	------	-----

	1	1	2	4	1	4	4.2243	1.0561	1.3298
ar_opti_foc_obj	1	1	2	4	1	4	4.2243	1.0561	1.3298
ar_opti_save_frac	2	2	2	4	4	1	1.664	0.416	0.2284
ar_opti_save_level	3	3	2	4	1	4	0.80247	0.20062	0.37807
xxx TABLE:ar_opti_foc_obj	xxxxxxxxxxxxxxxxxxxxxx								
	c1	c2	c3	c4					
	-----	-----	-----	-----					
r1	1.0555	-0.63965	1.2003	2.6081					
xxx TABLE:ar_opti_save_frac	xxxxxxxxxxxxxxxxxxxxxx								
	c1								

r1	0.33086								
r2	0.13278								
r3	0.57575								
r4	0.62461								
xxx TABLE:ar_opti_save_level	xxxxxxxxxxxxxxxxxxxxxx								
	c1	c2	c3	c4					
	-----	-----	-----	-----					
r1	0.37401	-0.070015	-0.15125	0.64972					

5.3.3 Test FF_OPTIM_MZOOM_SAVEZONE 8 Individuals 3 Iterations 10 Points Per Iteration, 0.25 zoom in ratio

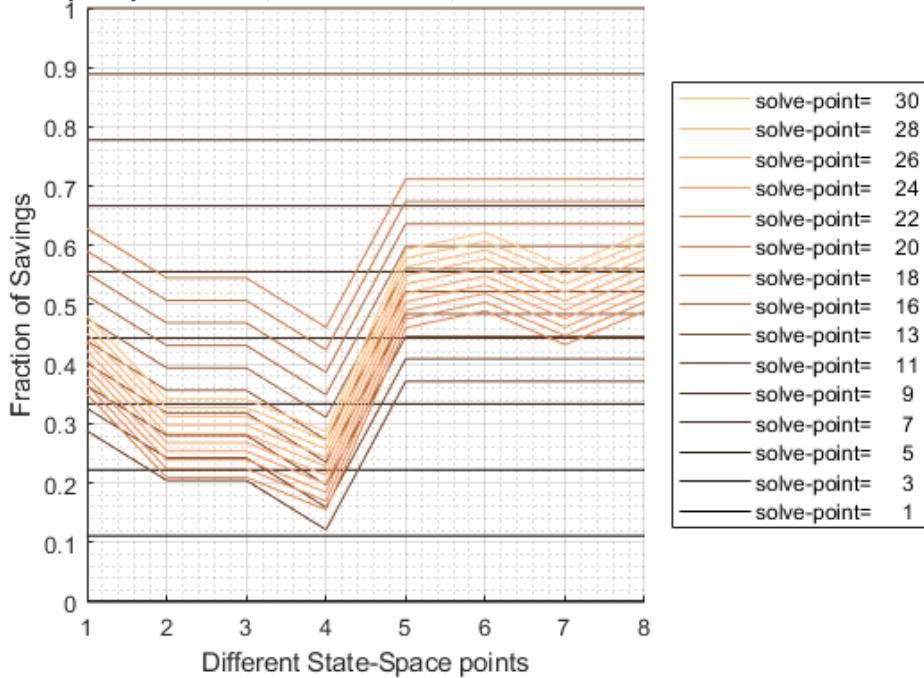
10 grid points per iteration, and 3 iterations.

```
% Generate the state-space and function
rng(123);
it_draws = 8; % must be even number
ar_z1 = exp(rand([it_draws,1])*3-1.5);
ar_z2 = exp(rand([it_draws,1])*3-1.5);
ar_r = (rand(it_draws,1)*10.0);
ar_beta = [rand(round(it_draws/2),1)*0.9+0.1; rand(round(it_draws/2),1)*0.9+1];
fc_util = @(x) ffi_intertemporal_util(x, ar_z1, ar_z2, ar_r, ar_beta);
% Call Function
bl_verbose = true;
bl_timer = true;
mp_mzoom_ctrlinfo = containers.Map('KeyType','char', 'ValueType','any');
mp_mzoom_ctrlinfo('it_mzoom_jnt_pnts') = 10;
mp_mzoom_ctrlinfo('it_mzoom_max_iter') = 3;
mp_mzoom_ctrlinfo('it_mzoom_zm_ratio') = 0.25;
[fl_opti_save_frac, fl_opti_save_level] = ...
    ff optim_mzoom_savezone(fc.util, bl verbose, bl timer, mp.mzoom_ctrlinfo);
```

1	"point=7"	0.66666	0.66666	0.66666	0.66666	0.66666	0.66666	0.66666	0.66666
1	"point=8"	0.77777	0.77777	0.77777	0.77777	0.77777	0.77777	0.77777	0.77777
1	"point=9"	0.88888	0.88888	0.88888	0.88888	0.88888	0.88888	0.88888	0.88888
1	"point=10"	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999
2	"point=1"	0.28788	0.20455	0.20455	0.12122	0.37121	0.37121	0.37121	0.37121
2	"point=2"	0.32576	0.24243	0.24243	0.1591	0.40909	0.40909	0.40909	0.40909
2	"point=3"	0.36364	0.28031	0.28031	0.19698	0.44697	0.44697	0.44697	0.44697
2	"point=4"	0.40152	0.31819	0.31819	0.23485	0.48485	0.48485	0.48485	0.48485
2	"point=5"	0.4394	0.35606	0.35606	0.27273	0.52273	0.52273	0.52273	0.52273
2	"point=6"	0.47727	0.39394	0.39394	0.31061	0.5606	0.5606	0.5606	0.5606
2	"point=7"	0.51515	0.43182	0.43182	0.34849	0.59848	0.59848	0.59848	0.59848
2	"point=8"	0.55303	0.4697	0.4697	0.38637	0.63636	0.63636	0.63636	0.63636
2	"point=9"	0.59091	0.50758	0.50758	0.42424	0.67424	0.67424	0.67424	0.67424
2	"point=10"	0.62879	0.54545	0.54545	0.46212	0.71212	0.71212	0.71212	0.71212
3	"point=1"	0.34987	0.20972	0.20972	0.15479	0.46161	0.49001	0.49001	0.49001
3	"point=2"	0.3645	0.22435	0.22435	0.16943	0.47624	0.50465	0.50465	0.50465
3	"point=3"	0.37913	0.23899	0.23899	0.18406	0.49087	0.51928	0.51928	0.51928
3	"point=4"	0.39377	0.25362	0.25362	0.1987	0.50551	0.53392	0.53392	0.53392
3	"point=5"	0.4084	0.26826	0.26826	0.21333	0.52014	0.54855	0.54855	0.54855
3	"point=6"	0.42304	0.28289	0.28289	0.22797	0.53478	0.56319	0.56319	0.56319
3	"point=7"	0.43767	0.29752	0.29752	0.2426	0.54941	0.57782	0.57782	0.57782
3	"point=8"	0.45231	0.31216	0.31216	0.25724	0.56405	0.59246	0.59246	0.59246
3	"point=9"	0.46694	0.32679	0.32679	0.27187	0.57868	0.60709	0.60709	0.60709
3	"point=10"	0.48158	0.34143	0.34143	0.28651	0.59332	0.62173	0.62173	0.62173

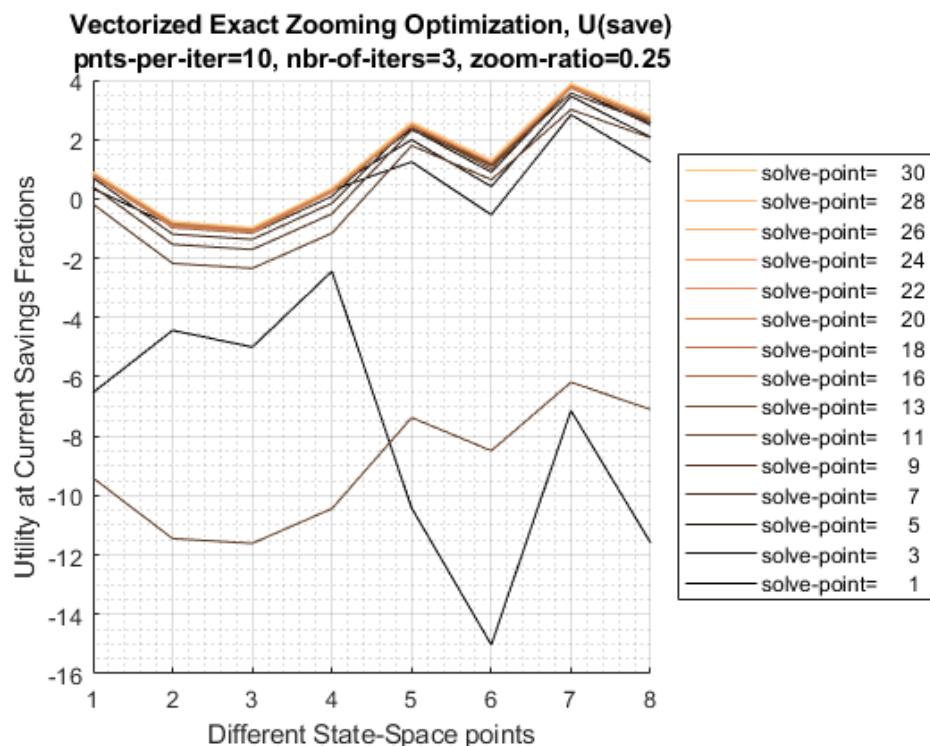
Vectorized Exact Zooming Optimization, Savings Fractions

pnts-per-iter=10, nbr-of-iters=3, zoom-ratio=0.25



iter	cl_row_names_a	Var1	Var2	Var3	Var4	Var5	Var6
1	"point=1"	-6.5286	-4.4312	-4.9951	-2.4407	-10.415	-15.025
1	"point=2"	0.34227	-0.90966	-1.148	0.28691	1.2451	-0.53687
1	"point=3"	0.7287	-0.77242	-0.98657	0.36508	1.9879	0.4163
1	"point=4"	0.87872	-0.76818	-0.96816	0.33477	2.3463	0.89785
1	"point=5"	0.91222	-0.83811	-1.028	0.24031	2.5277	1.1666
1	"point=6"	0.85648	-0.97408	-1.1562	0.085331	2.5867	1.2933

1	"point=7"	0.70558	-1.1905	-1.3663	-0.14666	2.5296	1.2915
1	"point=8"	0.41577	-1.5358	-1.7061	-0.50502	2.319	1.1277
1	"point=9"	-0.17716	-2.1767	-2.3424	-1.1573	1.7947	0.64395
1	"point=10"	-9.4046	-11.446	-11.608	-10.437	-7.3721	-8.4872
2	"point=1"	0.8347	-0.78233	-0.99938	0.30205	2.4239	1.0081
2	"point=2"	0.87277	-0.76475	-0.97586	0.34105	2.4846	1.0983
2	"point=3"	0.89748	-0.75933	-0.96536	0.36018	2.5303	1.1709
2	"point=4"	0.91044	-0.76388	-0.96549	0.36559	2.5622	1.2275
2	"point=5"	0.91269	-0.7771	-0.97477	0.36049	2.581	1.269
2	"point=6"	0.90477	-0.79823	-0.99237	0.34672	2.5867	1.296
2	"point=7"	0.88684	-0.8269	-1.0178	0.32535	2.5793	1.3084
2	"point=8"	0.85872	-0.86304	-1.051	0.29697	2.5578	1.3055
2	"point=9"	0.81987	-0.90685	-1.0921	0.26182	2.5209	1.2862
2	"point=10"	0.76932	-0.95877	-1.1415	0.21989	2.4664	1.2483
3	"point=1"	0.88992	-0.7791	-0.99528	0.33777	2.5443	1.234
3	"point=2"	0.8979	-0.77144	-0.98526	0.3479	2.5562	1.251
3	"point=3"	0.90413	-0.7658	-0.97741	0.35543	2.5661	1.2659
3	"point=4"	0.90869	-0.762	-0.97154	0.3607	2.5741	1.2785
3	"point=5"	0.91163	-0.75989	-0.96746	0.36397	2.5801	1.289
3	"point=6"	0.91299	-0.75934	-0.96506	0.36546	2.5842	1.2974
3	"point=7"	0.91281	-0.76025	-0.96421	0.36532	2.5864	1.3035
3	"point=8"	0.91112	-0.76255	-0.96482	0.3637	2.5866	1.3074
3	"point=9"	0.90792	-0.76615	-0.96683	0.3607	2.5849	1.3091
3	"point=10"	0.90324	-0.77102	-0.97016	0.35641	2.5811	1.3085



Elapsed time is 0.997040 seconds.

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx  
CONTAINER NAME: mp_container_map ND Array (Matrix etc)  
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std
	-	---	----	-----	----	----	-----	-----	-----
ar_opti_foc_obj	1	1	2	8	1	8	10.125	1.2656	1.731

```

ar_opti_save_frac    2   2   2   8   8   1   3.3843   0.42304   0.15074
ar_opti_save_level   3   3   2   8   1   8   4.965    0.62062   0.71498

xxx TABLE:ar_opti_foc_obj xxxxxxxxxxxxxxxxxxxxxxxx
      c1       c2       c3       c4       c5       c6       c7       c8
      -----  -----
r1  0.91163 -0.75989 -0.96506  0.36397  2.5864  1.3074  3.8892  2.7911

xxx TABLE:ar_opti_save_frac xxxxxxxxxxxxxxxxxxxxxxxx
      c1
      -----
r1  0.4084
r2  0.26826
r3  0.28289
r4  0.21333
r5  0.54941
r6  0.59246
r7  0.50637
r8  0.56319

xxx TABLE:ar_opti_save_level xxxxxxxxxxxxxxxxxxxxxxxx
      c1       c2       c3       c4       c5       c6       c7       c8
      -----  -----
r1  0.53854 -0.050976  0.053729  0.0013119 1.0103  0.45895  2.098   0.85508

```

5.3.4 Test FF_OPTIM_MZOOM_SAVEZRONE Speed

Test Speed doing 6.25 million state-spcae points for a savings problem:

```

% Generate the state-space and function
rng(123);
it_draws = 6250000; % must be even number
ar_z1 = exp(rand([it_draws,1])*3-1.5);
ar_z2 = exp(rand([it_draws,1])*3-1.5);
ar_r = (rand(it_draws,1)*10.0);
ar_beta = [rand(round(it_draws/2),1)*0.9+0.1; rand(round(it_draws/2),1)*0.9+1];
% ffi_intertemporal_max is a function in ff_optim_mlsec_savezrone for testing
fc_util = @(x) ffi_intertemporal_util(x, ar_z1, ar_z2, ar_r, ar_beta);
% Call Function
bl_verbose = false;
bl_timer = true;
% set parameters
mp_mzoom_ctrlinfo = containers.Map('KeyType','char', 'ValueType','any');
mp_mzoom_ctrlinfo('it_mzoom_jnt_pnts') = 20;
mp_mzoom_ctrlinfo('it_mzoom_max_iter') = 10;
mp_mzoom_ctrlinfo('it_mzoom_zm_ratio') = 0.25;
[ar_opti_save_frac, ar_opti_save_level] = ...
    ff_optim_mzoom_savezrone(fc_util, bl_verbose, bl_timer, mp_mzoom_ctrlinfo);

```

Elapsed time is 64.837799 seconds.

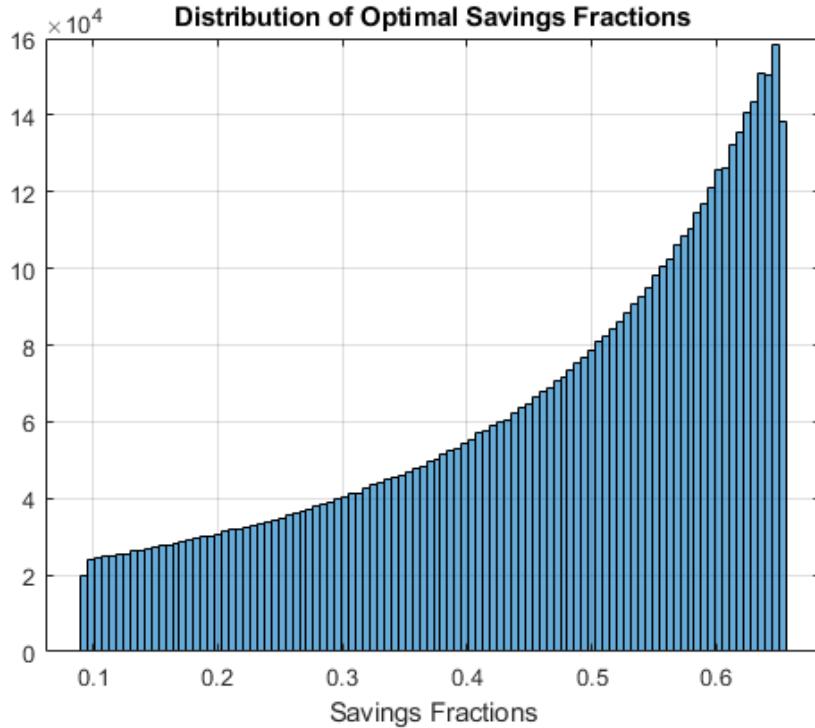
```

mp_container_map = containers.Map('KeyType','char', 'ValueType','any');
mp_container_map('ar_opti_save_frac') = ar_opti_save_frac;
mp_container_map('ar_opti_save_level') = ar_opti_save_level;
mp_container_map('ar_opti_save_frac_notnan') = ar_opti_save_frac(~isnan(ar_opti_save_frac));
ff_container_map_display(mp_container_map);

```

```
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      i   idx  ndim  numel   rowN   colN   sum
      -   ---  ----  -----  -----  -----  -----
ar_opti_save_frac       1     1     2    6.25e+06  6.25e+06     1  2.8839e+06  0.
ar_opti_save_frac_notnan 2     2     2    6.25e+06  6.25e+06     1  2.8839e+06  0.
ar_opti_save_level      3     3     2    6.25e+06  6.25e+06     1  2.9481e+06  0.

figure();
histogram(ar_opti_save_frac(~isnan(ar_opti_save_frac)),100);
title('Distribution of Optimal Savings Fractions');
xlabel('Savings Fractions');
grid on;
```



5.3.5 Define Two Period Intertemporal Log Utility No Shock Utility Function

See [Household's Utility Maximization Problem and Two-Period Borrowing and Savings Problem given Endowments](#).

```
function [ar_util, ar_saveborr_level] = ...
ffi_intertemporal_util(ar_saveborr_frac, z1, z2, r, beta)

ar_saveborr_level = ar_saveborr_frac.*((z1+z2)/(1+r)) - z2/(1+r);
ar_util = log(z1 - ar_saveborr_level) + beta.*log(ar_saveborr_level.*((1+r) + z2));

end
```

Chapter 6

Graphs

6.1 FF_GRAPH_GRID Examples: X, Y and Color Line Plots

Go back to [fan's MEconTools Toolbox \(bookdown\)](#), [Matlab Code Examples Repository \(bookdown\)](#), or [Math for Econ with Matlab Repository \(bookdown\)](#).

This is the example vignette for function: `ff_graph_grid` from the [MEconTools Package](#). This function can graph out value and policy functions given one state vector (x-axis), conditional on other states (line groups). Can handle a few lines (scatter + lines), or many groups (jet spectrum). Can handle policy and value function graphs, or distributional plots.

6.1.1 Test FF_GRAPH_GRID Defaults

Call the function with defaults.

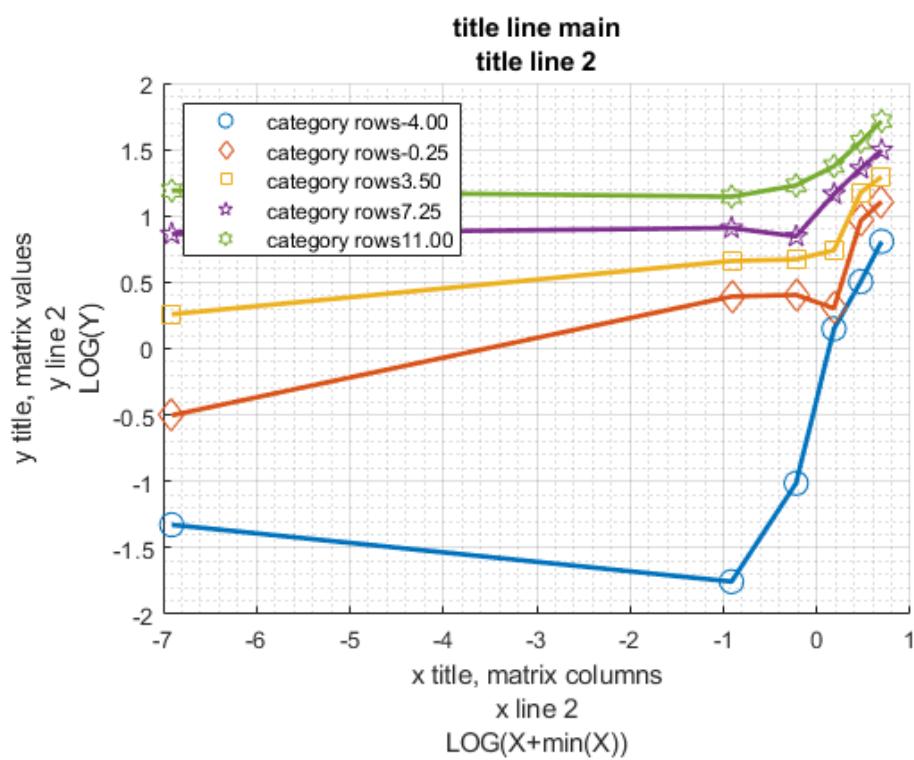
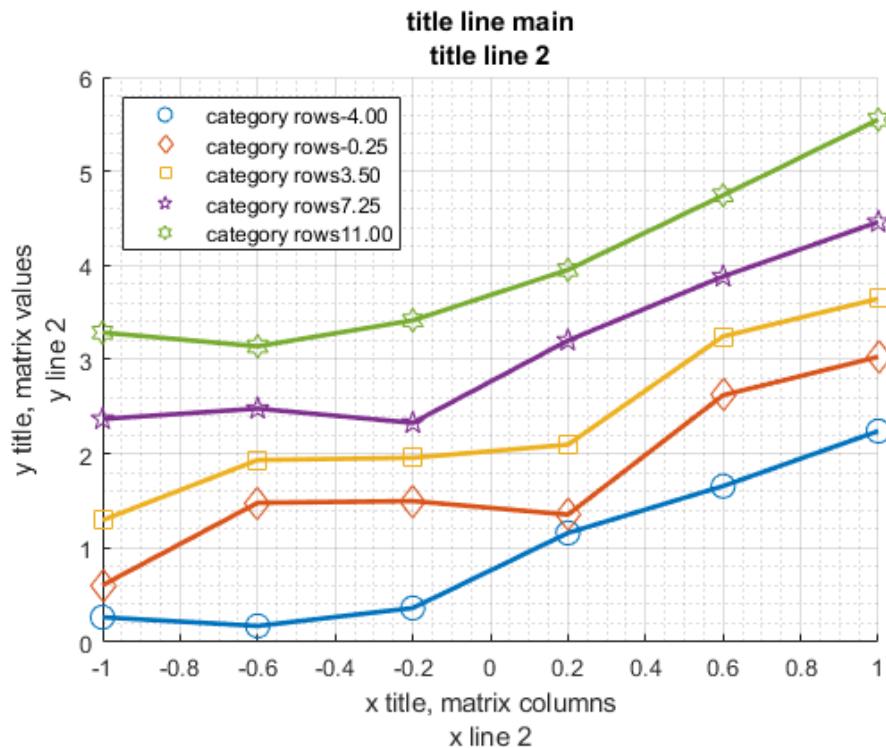
```
ff_graph_grid();
```

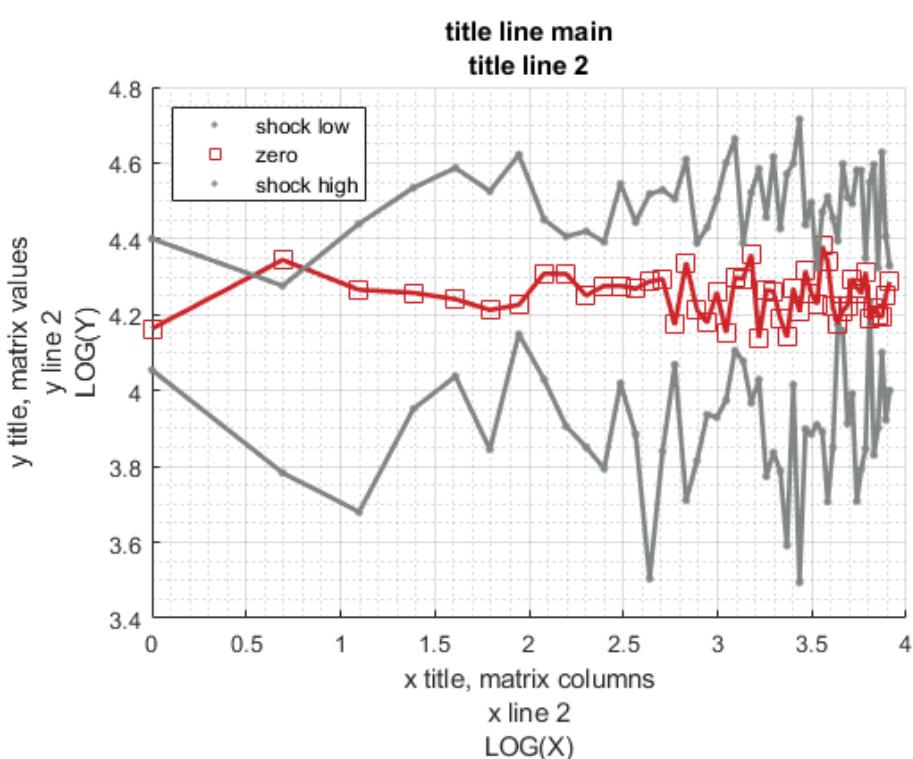
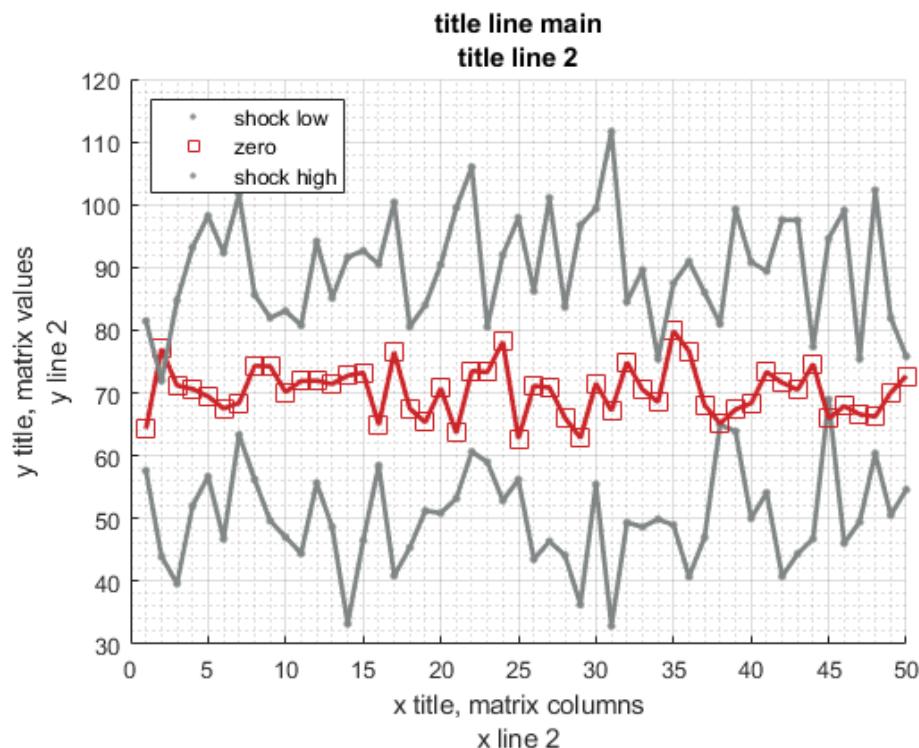
6.1.2 Test FF_GRAPH_GRID Random Matrix Pick Markers and Colors

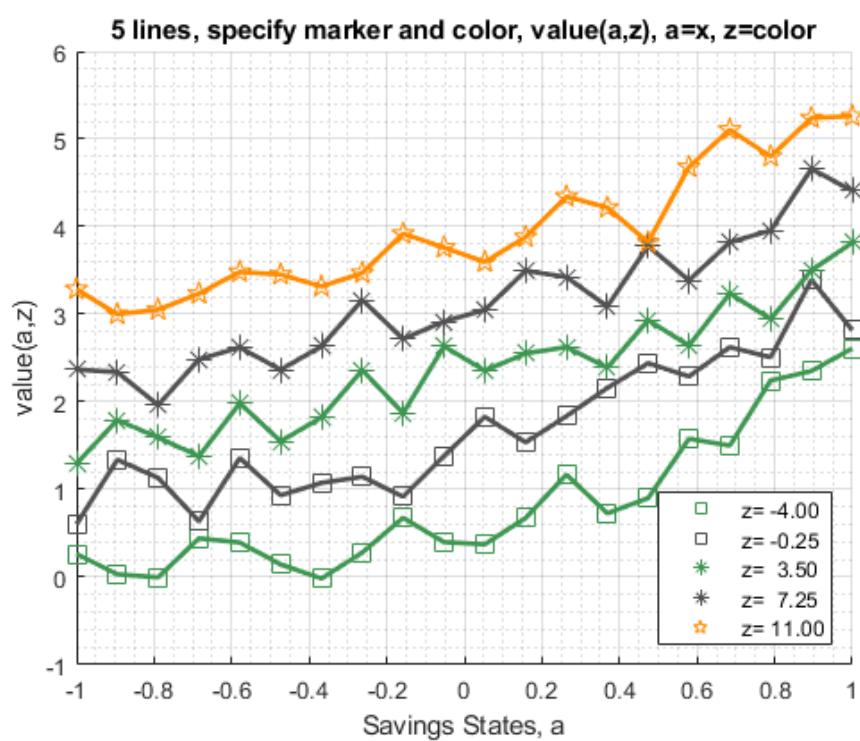
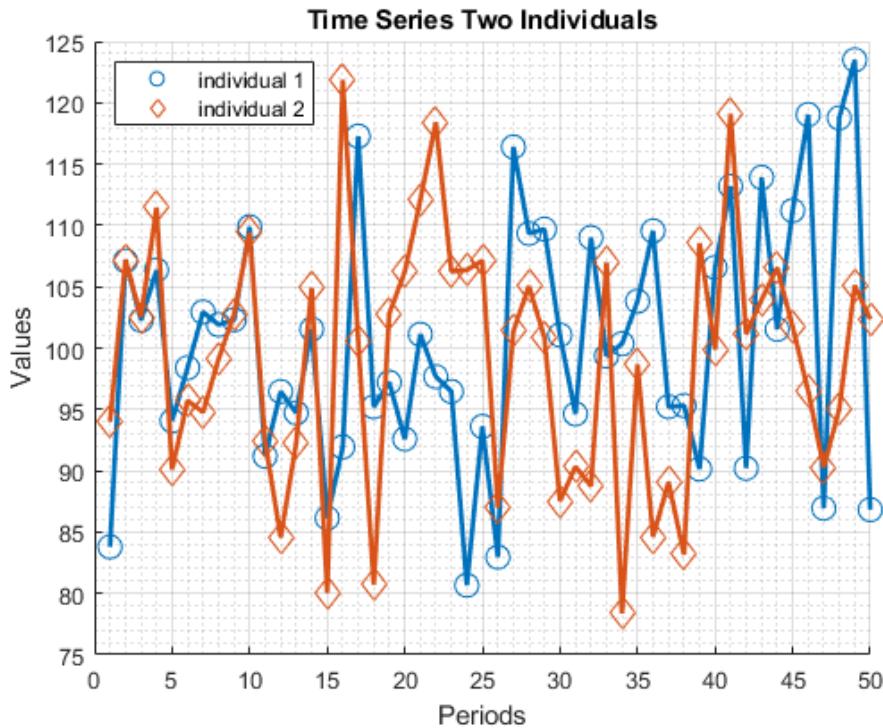
Call the function with defaults. Graph a matrix, each row of the matrix is a separate line, each column a point along the x-axis, value of the matrix are plotting on the y-axis.

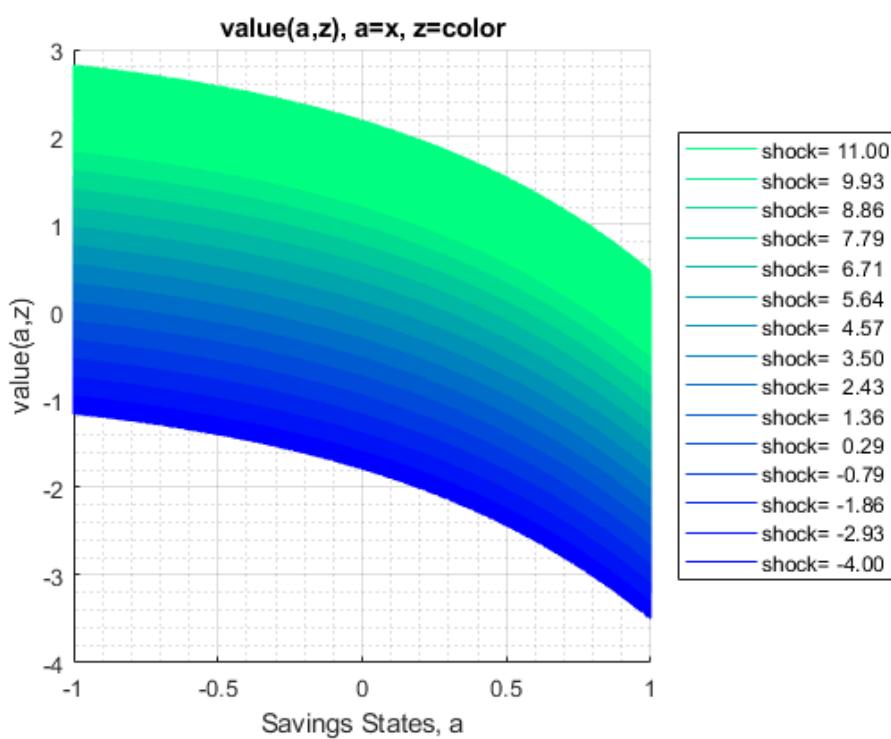
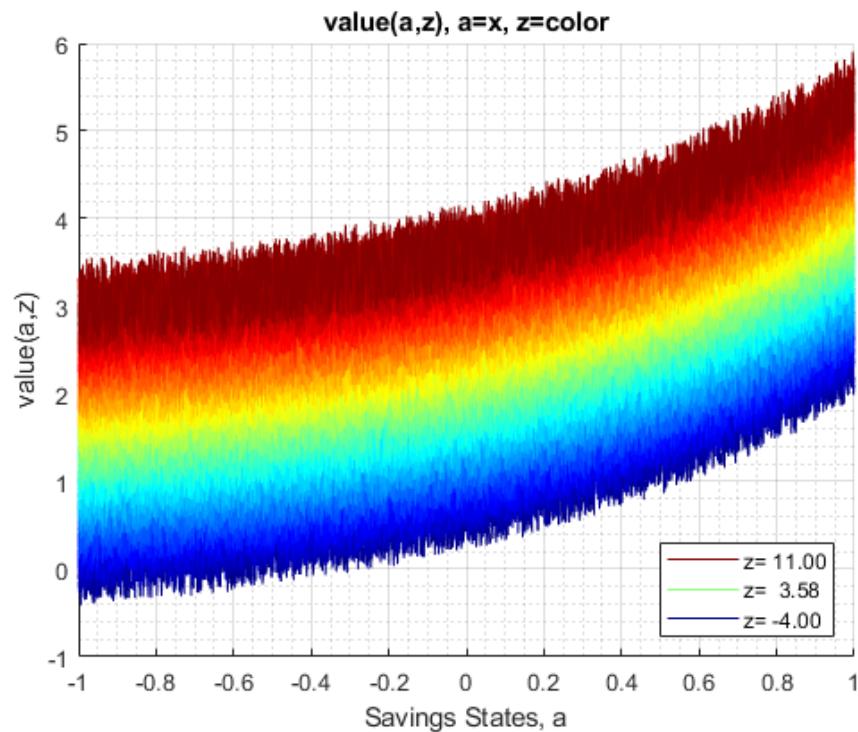
- ar_row_grid: the values associated with each row, what will show up in the legend
- ar_col_grid: the values associated with each column
- mt_support_graph: various controls, color, etc...

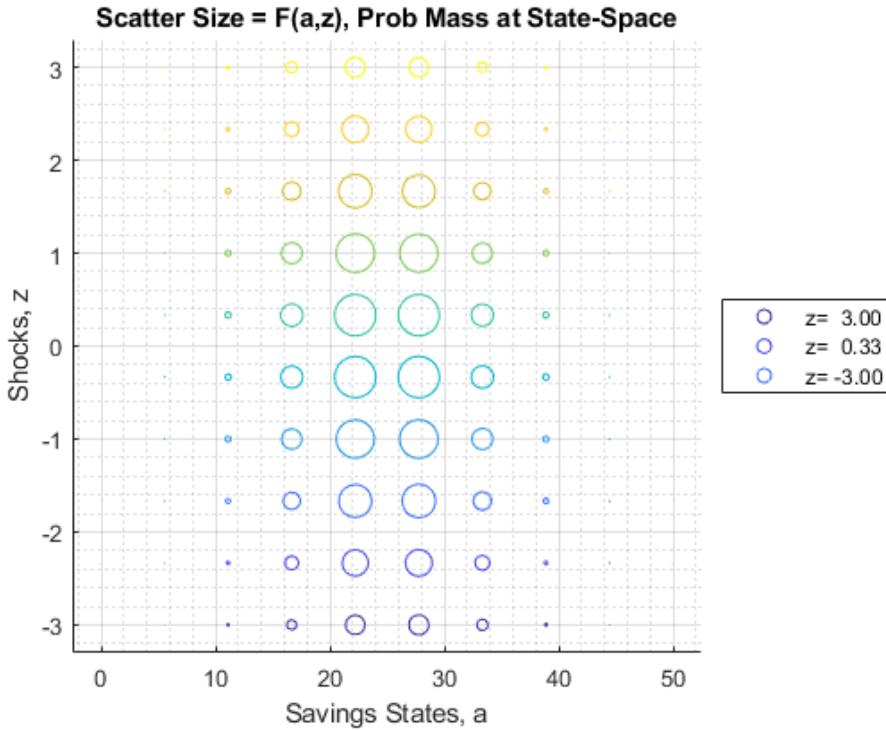
```
rng(123);
mt_value = [normrnd(50,10,[1, 50]); ...
            normrnd(70,5,[1, 50]);...
            normrnd(90,10,[1, 50])];
ar_row_grid = ["shock low", "zero", "shock high"];
ar_col_grid = 1:50;
mp_support_graph = containers.Map('KeyType', 'char', 'ValueType', 'any');
mp_support_graph('cl_scatter_shapes') = { '.', 's' , '.' };
```











```
mp_support_graph('cl_colors') = {'gray', 'red', 'gray'};
ff_graph_grid(mt_value, ar_row_grid, ar_col_grid, mp_support_graph);
```

6.1.3 Test FF_GRAPH_GRID Two Random Normal Lines and Labels

There are two autoregressive time series, plot out the time two time series.

```
% Generate the two time series
rng(456);
mt_value = normrnd(100,10,[2, 50]);
ar_row_grid = ["individual 1", "individual 2"];
ar_col_grid = 1:50;
mp_support_graph = containers.Map('KeyType', 'char', 'ValueType', 'any');
mp_support_graph('cl_st_graph_title') = {'Time Series Two Individuals'};
mp_support_graph('cl_st_ytitle') = {'Values'};
mp_support_graph('cl_st_xttitle') = {'Periods'};
mp_support_graph('bl_graph_logy') = false; % do not log
ff_graph_grid(mt_value, ar_row_grid, ar_col_grid, mp_support_graph);
```

6.1.4 Test FF_GRAPH_GRID 6 Lines Pick Marker and Colors

Plot many lines, with auto legend.

```
% Generate some Data
rng(456);
ar_row_grid = linspace(-4, 11, 5);
ar_col_grid = linspace(-1, 1, 20);
rng(123);
mt_value = 0.2*ar_row_grid' + exp(ar_col_grid) + rand([length(ar_row_grid), length(ar_col_grid)]);
% container map settings
mp_support_graph = containers.Map('KeyType', 'char', 'ValueType', 'any');
mp_support_graph('cl_st_graph_title') = {'5 lines, specify marker and color, value(a,z), a=x, z=colo';
mp_support_graph('cl_st_ytitle') = {'value(a,z)'};
mp_support_graph('cl_st_xttitle') = {'Savings States, a'};
mp_support_graph('st_legend_loc') = 'southeast';
```

```

mp_support_graph('bl_graph_logy') = false; % do not log
mp_support_graph('st_rowvar_name') = 'z=';
mp_support_graph('it_legend_select') = 3; % how many shock legends to show
mp_support_graph('st_rounding') = '6.2f'; % format shock legend
mp_support_graph('cl_scatter_shapes') = {'s', 's', '*', '*', 'p'};
mp_support_graph('cl_colors') = {'green', 'black', 'green', 'black', 'orange'};
% Call function
ff_graph_grid(mt_value, ar_row_grid, ar_col_grid, mp_support_graph);

```

6.1.5 Test FF_GRAPH_GRID Many Lines

Plot many lines, with auto legend.

```

% Generate some Data
rng(456);
ar_row_grid = linspace(-4, 11, 100);
ar_col_grid = linspace(-1, 1, 1000);
rng(123);
mt_value = 0.2*ar_row_grid' + exp(ar_col_grid) + rand([length(ar_row_grid), length(ar_col_grid)]);
% container map settings
mp_support_graph = containers.Map('KeyType', 'char', 'ValueType', 'any');
mp_support_graph('cl_st_graph_title') = {'value(a,z)', a=x, z=color'};
mp_support_graph('cl_st_ytitle') = {'value(a,z)'};
mp_support_graph('cl_st_xtitle') = {'Savings States', a'};
mp_support_graph('st_legend_loc') = 'southeast';
mp_support_graph('bl_graph_logy') = false; % do not log
mp_support_graph('st_rowvar_name') = 'z=';
mp_support_graph('it_legend_select') = 3; % how many shock legends to show
mp_support_graph('st_rounding') = '6.2f'; % format shock legend
mp_support_graph('cl_colors') = 'jet'; % any predefined matlab colormap
% Call function
ff_graph_grid(mt_value, ar_row_grid, ar_col_grid, mp_support_graph);

```

6.1.6 Test FF_GRAPH_GRID Many Lines Legend Exogenous

Plot many lines, exogenously set legend

```

% Generate the two time series
rng(456);
ar_row_grid = linspace(-4, 11, 15);
ar_col_grid = linspace(-1, 1, 100000);
rng(123);
mt_value = 0.2*ar_row_grid' - exp(ar_col_grid) + rand([length(ar_row_grid), length(ar_col_grid)]);
% setting shock vector name exogenously here
ar_row_grid = string(num2str(ar_row_grid', "shock=%6.2f"));
% container map settings
mp_support_graph = containers.Map('KeyType', 'char', 'ValueType', 'any');
mp_support_graph('cl_st_graph_title') = {'value(a,z)', a=x, z=color'};
mp_support_graph('cl_st_ytitle') = {'value(a,z)'};
mp_support_graph('cl_st_xtitle') = {'Savings States', a'};
mp_support_graph('st_legend_loc') = 'eastoutside';
mp_support_graph('bl_graph_logy') = false; % do not log
mp_support_graph('it_legend_select') = 15;
mp_support_graph('cl_colors') = 'winter'; % any predefined matlab colormap
% Call function
ff_graph_grid(mt_value, ar_row_grid, ar_col_grid, mp_support_graph);

```

6.1.7 Test FF_GRAPH_GRID Joint Probability Mass Output as Scatter Size

Along two dimensions of the state-space, we might want to visualize the probability mass distribution $P(a,z)$. We will show A and Z as the X and Y dimensions, and use Scatter size for mass at each point.

In the default mode, each ar_row_grid can be a string array, providing labels for each data matrix row, shown with different colors. Here, the ar_row_grid must be numeric.

```
% Joint Normal Mass
rng(456);
mu = [0 25];
sigma = [3 -0.3; -0.3 25];
ar_z = linspace(-3, 3, 10);
ar_a = linspace(0, 50, 10);
[mt_a, mt_z] = meshgrid(ar_a, ar_z);
mt_x = [mt_z(:) mt_a(:)];
ar_prob = mvnpdf(mt_x, mu, sigma);
mt_prob = reshape(ar_prob,length(ar_a),length(ar_z));
mt_prob = mt_prob/sum(mt_prob, 'all');
% container map settings
mp_support_graph = containers.Map('KeyType', 'char', 'ValueType', 'any');
mp_support_graph('cl_st_graph_title') = {'Scatter Size = F(a,z), Prob Mass at State-Space'};
mp_support_graph('cl_st_ytitle') = {'Shocks, z'};
mp_support_graph('cl_st_xtitle') = {'Savings States, a'};
mp_support_graph('st_legend_loc') = 'eastoutside';
mp_support_graph('bl_graph_logy') = false; % do not log
mp_support_graph('st_rowvar_name') = 'z=';
mp_support_graph('it_legend_select') = 3; % how many shock legends to show
mp_support_graph('st_rounding') = '6.2f'; % format shock legend
mp_support_graph('cl_colors') = 'parula'; % any predefined matlab colormap
mp_support_graph('it_dist_csize_multiple') = 5000;

% Call function
ar_row_grid = ar_z;
ar_col_grid = ar_a;
st_figtype = 'dist';
ff_graph_grid(mt_prob, (ar_z), ar_col_grid, mp_support_graph, st_figtype);
```

Chapter 7

Support Tools

7.1 FF_CONTAINER_MAP_DISPLAY Examples

Go back to [fan's MEconTools Toolbox \(bookdown\)](#), [Matlab Code Examples Repository \(bookdown\)](#), or [Math for Econ with Matlab Repository \(bookdown\)](#).

This is the example vignette for function: `ff_container_map_display` from the [MEconTools Package](#). This function summarizes statistics of matrixes stored in a container map, as well as scalar, string, function and other values stored in container maps.

7.1.1 Test FF_CONTAINER_MAP_DISPLAY Defaults

Call the function with defaults.

```
ff_container_map_display();
```

```
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      i    idx   ndim   numel   rowN   colN     sum   mean   std
      --  ----  -----  -----  ----  ----  -----  -----  -----
mat_1       1      7      2      12      3      4    6.5142  0.54285  0.2232
mat_2       2      8      2     2650     50     53   1313.3  0.49559  0.29232
mat_2_boolean 3      9      2     2650     50     53    1361   0.51358  0.49991
mat_3       4     10      2      4      2      2    1.8111  0.45277  0.45111
tensor_1     5     15      3      16      2      8    7.3043  0.45652  0.27787
tensor_2     6     16      3      75      3     25    40.195  0.53593  0.29044
tensor_3     7     17      2      4      1      4    1.6926  0.42315  0.37389
tesseract_1 8     18      4      72      3     24    34.321  0.47669  0.26374
tesseract_2 9     19      4      20      2     10    8.4191  0.42096  0.28981
tesseract_bl_3 10    20      4      10      1     10      3      0.3    0.48305

xxx TABLE:mat_1 xxxxxxxxxxxxxxxxxxxx
      c1        c2        c3        c4
      ----  -----  -----  -----
r1  0.69647  0.55131  0.98076  0.39212
r2  0.28614  0.71947  0.68483  0.34318
r3  0.22685  0.42311  0.48093  0.72905

xxx TABLE:mat_2 xxxxxxxxxxxxxxxxxxxx
      c1        c2        c3        c4        c50       c51       c52       c53
      ----  -----  -----  -----  -----

```

	c1	c2	c3	c4	c50	c51	c52	c53
r1	0.43857	0.6249	0.17108	0.56564	0.072152	0.67855	0.61667	0.540
r2	0.059678	0.67469	0.82911	0.084904	0.63289	0.27236	0.32528	0.249
r3	0.39804	0.84234	0.33867	0.58267	0.046367	0.44513	0.075047	0.78
r4	0.738	0.083195	0.55237	0.81484	0.50561	0.11117	0.59532	0.356
r5	0.18249	0.76368	0.57855	0.33707	0.10653	0.028681	0.7435	0.918
r46	0.6813	0.55326	0.88786	0.69983	0.83758	0.16382	0.74191	0.0656
r47	0.87546	0.85445	0.69631	0.66117	0.97069	0.79092	0.42466	0.787
r48	0.51042	0.38484	0.44033	0.049097	0.017768	0.33302	0.24401	0.979
r49	0.66931	0.31679	0.43821	0.7923	0.12979	0.75311	0.79466	0.0790
r50	0.58594	0.35426	0.7651	0.51872	0.86415	0.58281	0.84795	0.45
<hr/>								
xxx TABLE:mat_2_boolean xxxxxxxxxxxxxxxxxxxx								
	c1	c2	c3	c4	c50	c51	c52	c53
r1	true	false	false	true	true	false	true	true
r2	true	false	true	true	false	false	true	true
r3	false	true	false	true	false	true	false	true
r4	false	true	false	false	false	true	true	true
r5	true	true	true	false	true	false	false	true
r46	false	true	true	false	true	true	true	true
r47	true	true	true	true	true	true	false	false
r48	true	false	false	false	true	true	false	true
r49	true	true	false	true	true	true	false	false
r50	false	false	false	false	false	false	false	false
<hr/>								
xxx TABLE:mat_3 xxxxxxxxxxxxxxxxxxxx								
	c1	c2						
r1	0.00012471	0.13253						
r2	0.88615	0.79226						
<hr/>								
xxx TABLE:tensor_1 xxxxxxxxxxxxxxxxxxxx								
	c1	c2	c3	c4	c5	c6	c7	c8
r1	0.019363	0.34271	0.52167	0.53703	0.75756	0.68839	0.8345	0.26597
r2	0.018091	0.33355	0.11738	0.77857	0.81933	0.28644	0.6157	0.368
<hr/>								
xxx TABLE:tensor_2 xxxxxxxxxxxxxxxxxxxx								
	c1	c2	c3	c4	c22	c23	c24	c25
r1	0.51866	0.40495	0.48278	0.99731	0.46584	0.62976	0.035924	0.10505
r2	0.028692	0.37408	0.24149	0.35201	0.66054	0.87243	0.0024293	0.81088
r3	0.87339	0.19457	0.83212	0.15315	0.77859	0.96663	0.2501	0.8056
<hr/>								
xxx TABLE:tensor_3 xxxxxxxxxxxxxxxxxxxx								
	c1	c2	c3	c4				
r1	0.1219	0.5119	0.91553	0.14329				
<hr/>								
xxx TABLE:tesseract_1 xxxxxxxxxxxxxxxxxxxx								
	c1	c2	c3	c4	c21	c22	c23	c24

```

-----
r1  0.64531   0.59299   0.32115   0.67653   0.90328   0.56911   0.52562   0.12014
r2  0.74558   0.5007    0.46142   0.21384   0.35564   0.13732   0.155     0.23786
r3  0.91137   0.46403   0.18118   0.049919  0.46246   0.46842   0.75348   0.64547

xxx TABLE:tesseract_2 xxxxxxxxxxxxxxxxxxxx
      c1        c2        c3        c4        c7        c8        c9        c10
-----
r1  0.28898   0.48211   0.44359   0.97146   0.61782   0.65121   0.80715   0.11605
r2  0.094493  0.34941   0.17595   0.14192   0.16754   0.57097   0.043114  0.70518

xxx TABLE:tesseract_b1_3 xxxxxxxxxxxxxxxxxxxx
      c1        c2        c3        c4        c7        c8        c9        c10
-----
r1  false      false      true      true      false      true      false      false
-----

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      i        idx       value
-----
boolean_1    1         1         1
empty        2         2         NaN
mat_4        3         11        0.74898
string_float_1 4         13        1021.1
string_int_1  5         14        1021

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
String
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      i        idx       string
-----
list_string_1 "1"      "5"      "col1;col2;col3;col4"
list_string_2 "2"      "6"      "row1;row2;row3;row4"
string_1      "3"      "12"     "Table Name"

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
Functions
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      i        idx       functionString
-----
func1        "1"      "3"      "@(x)1+2+x"
func2        "2"      "4"      "@(x,y)x*1+sqrt(y)"

```

7.1.2 Test FF_CONTAINER_MAP_DISPLAY summarize Matrix Only

Three large matrixes, show summaries

```
% Create Container
mp_container_map = containers.Map('KeyType','char', 'ValueType','any');
```

```

rng(123);
mp_container_map('mat_1') = rand(100,100);
mp_container_map('mat_2') = rand(100,100)*2 + 1;
mp_container_map('mat_2_boolean') = (rand(100,100) > 0.5);
% Will only print
ff_container_map_display(mp_container_map);

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	co
	-	---	----	-----	---	---	-----	-----	-----	---
mat_1	1	1	2	10000	100	100	4982.3	0.49823	0.28829	0.
mat_2	2	2	2	10000	100	100	20029	2.0029	0.57632	0.
mat_2_boolean	3	3	2	10000	100	100	4995	0.4995	0.50002	1

7.1.3 Test FF_CONTAINER_MAP_DISPLAY Show Matrix Subset

A container map with three small matrixes, print only only 2 rows and 3 columns.

```

% Create Container
mp_container_map = containers.Map('KeyType','char', 'ValueType','any');
rng(789);
mp_container_map('mat_1') = rand(3,4);
mp_container_map('mat_2') = rand(50,53);
mp_container_map('mat_2_boolean') = (rand(50,53) > 0.5);
% Will only print
ff_container_map_display(mp_container_map, 2, 3);

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	co
	-	---	----	-----	---	---	-----	-----	-----	---
mat_1	1	1	2	12	3	4	4.9876	0.41564	0.33586	0.
mat_2	2	2	2	2650	50	53	1324.3	0.49973	0.28834	0.
mat_2_boolean	3	3	2	2650	50	53	1350	0.50943	0.50001	0.

```

xxx TABLE:mat_1 xxxxxxxxxxxxxxxxxxxx
      c1        c2        c3        c4
      -----  -----  -----  -----
      r1  0.32333  0.62442  0.01062  0.53815
      r3  0.79378  0.75889  0.11104  0.55157

```

```

xxx TABLE:mat_2 xxxxxxxxxxxxxxxxxxxx
      c1        c2        c52       c53
      -----  -----  -----  -----
      r1  0.72837  0.20976  0.74583  0.22321
      r50 0.52812    0.545   0.49521  0.29826

```

```

xxx TABLE:mat_2_boolean xxxxxxxxxxxxxxxx
      c1        c2        c52       c53
      -----  -----  -----  -----

```

r1	false	true	true	true
r50	true	false	false	true

Chapter 8

Data Structures

8.1 FF_SAVEBORR_GRID Example for Generating Asset Grid

Go back to fan's MEconTools Toolbox ([bookdown](#)), Matlab Code Examples Repository ([bookdown](#)), or Math for Econ with Matlab Repository ([bookdown](#)).

This is the example vignette for function: `ff_saveborr_grid` from the [MEconTools Package](#). This function generates variously spaced savings/borrowing states/choices grid.

8.1.1 Test FF_SAVEBORR_GRID Defaults

Call the function with defaults.

```
ff_saveborr_grid();

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      i     idx    ndim   numel   rowN   colN     sum   mean   std   coe
      -     ---    ----   -----   ----   ----   -----   -----   -----   -----
ar_fl_saveborr   1      1      2      25      25      1    385.93  15.437  15.324  0.9
xxx TABLE:ar_fl_saveborr xxxxxxxxxxxxxxxxx
      c1
      -----
      r1      1
      r2    1.0174
      r3    1.0982
      r4    1.2707
      r5    1.5557
      r6    1.9707
      r7    2.5312
      r8    3.2512
      r9    4.1434
      r10   5.2196
      r11   6.4912
      r12   7.9687
      r13   9.6621
      r14  11.581
```

```

r15    13.735
r16    16.132
r17    18.781
r18    21.691
r19    24.87
r20    28.324
r21    32.063
r22    36.093
r23    40.421
r24    45.054
r25      50

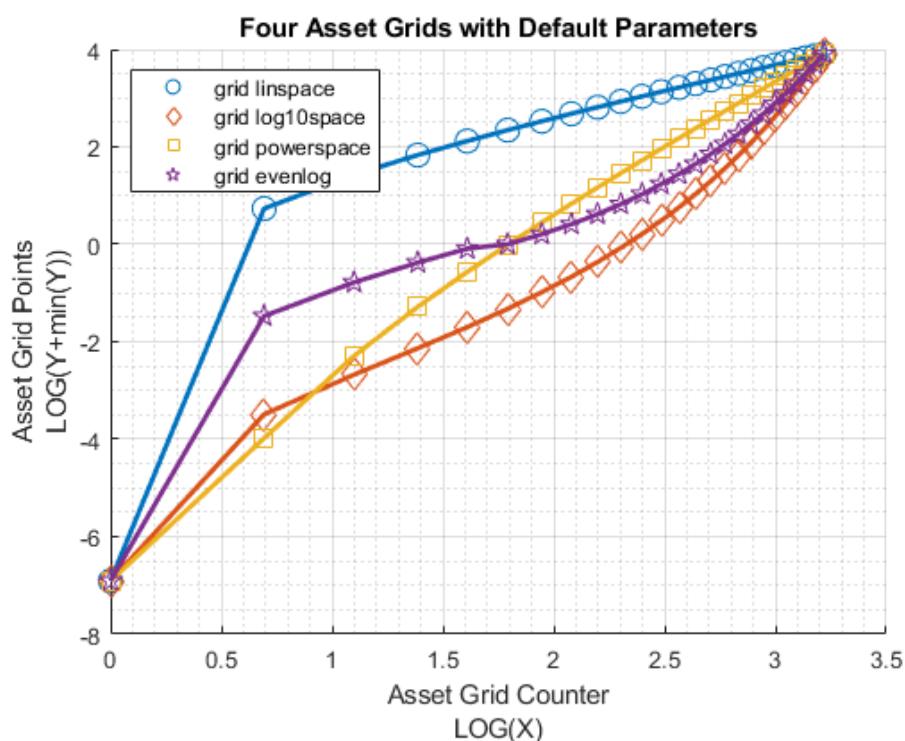
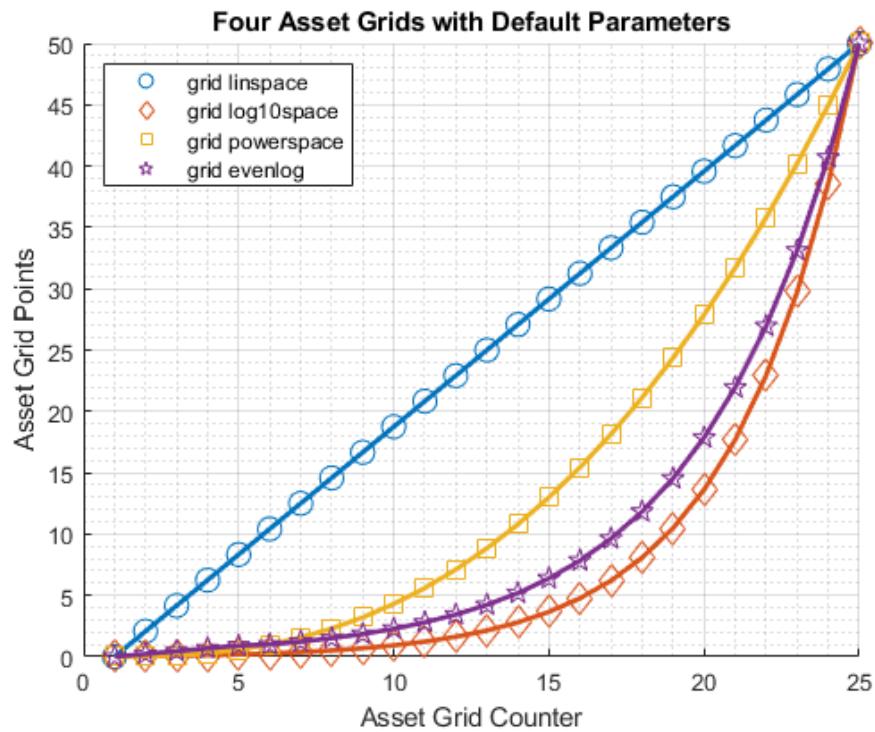
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
-----
```

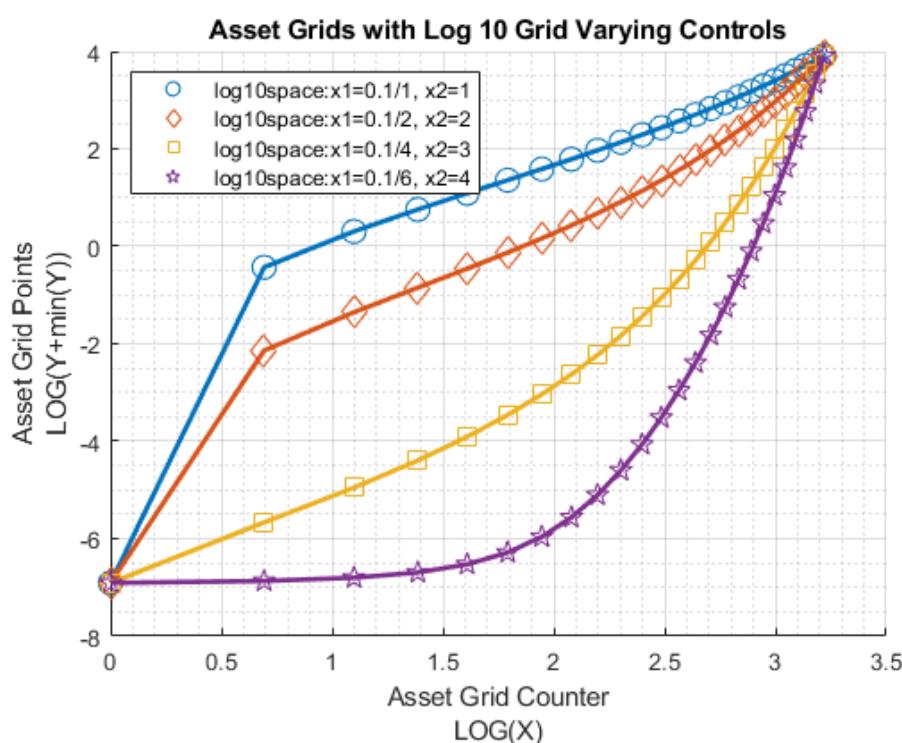
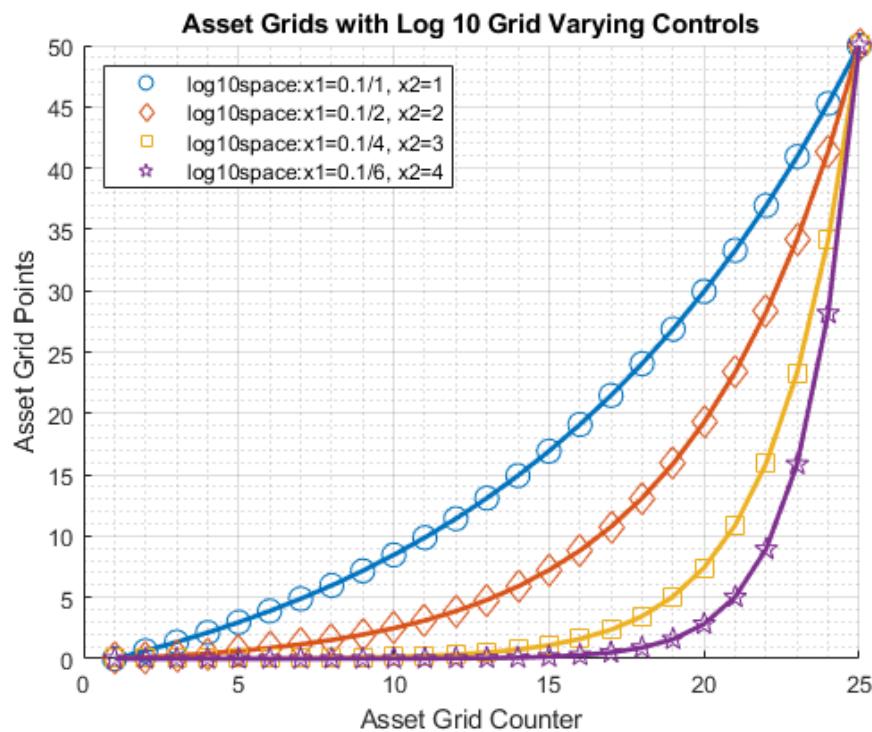
	i	idx	value
	-	---	-----
grid_evenlog_threshold	1	2	1
grid_log10space_x1	2	3	0.3
grid_log10space_x2	3	4	3
grid_powerspace_power	4	5	2.5

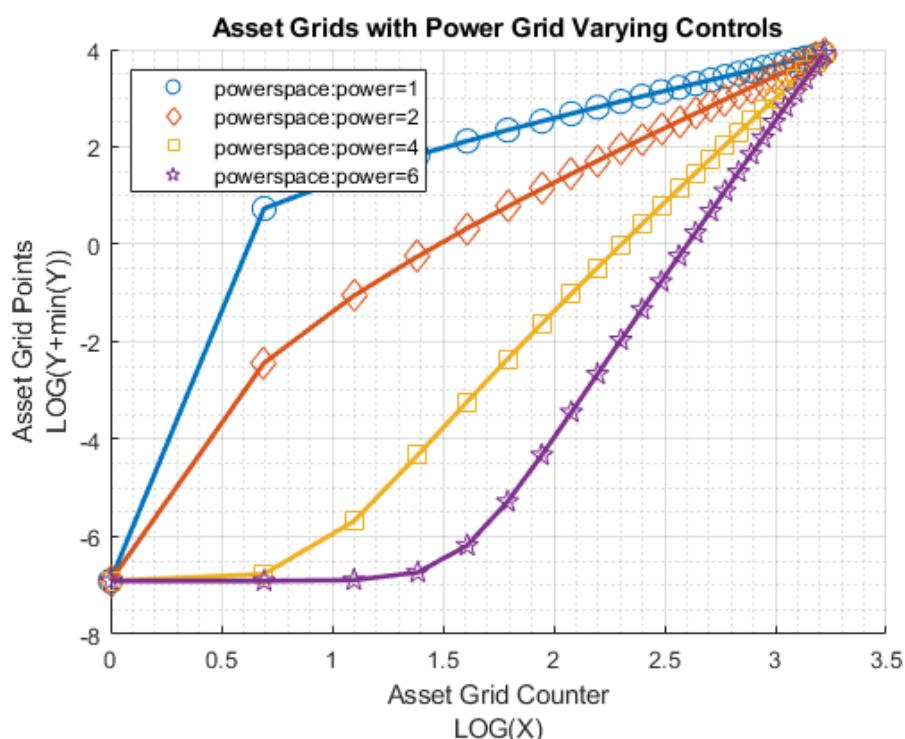
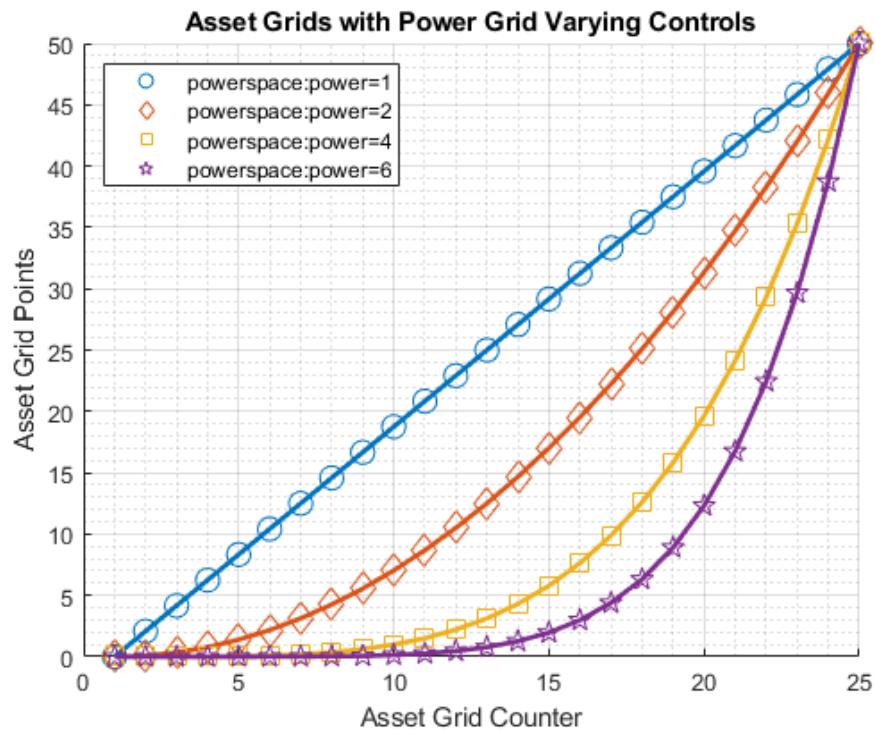
8.1.2 Test FF_SAVEBORR_GRID Default Linear Grid, Log Grid, Power Grid, Threshold Grid

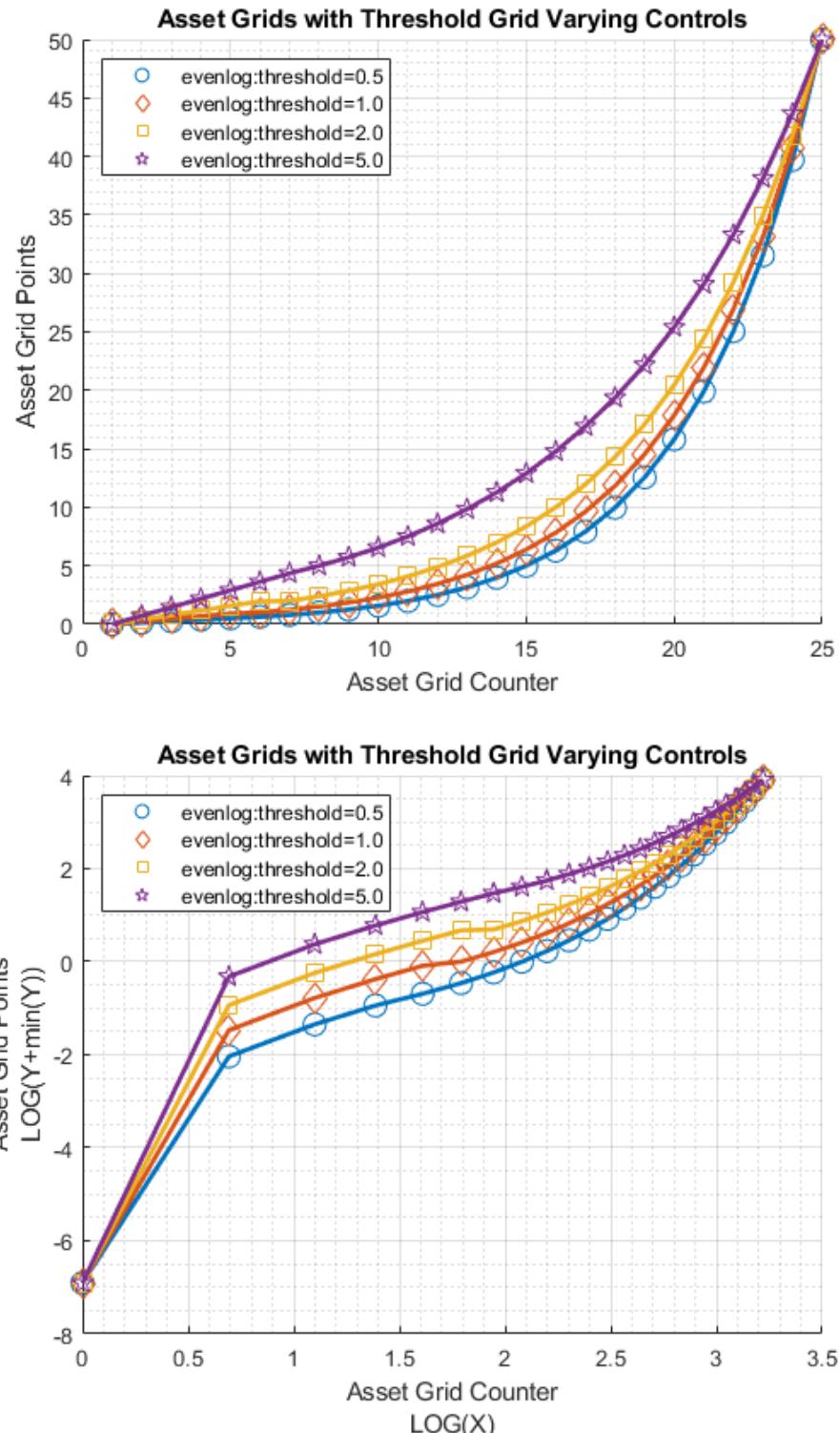
Call the function with defaults.

```
% Same min and max and grid points
[fl_a_min, fl_a_max, it_a_points] = deal(0,50,25);
% Four types of grid points
st_grid_type = 'grid_linspace';
[ar_fl_saveborr_linspace] = ff_saveborr_grid(fl_a_min, fl_a_max, it_a_points, st_grid_type);
st_grid_type = 'grid_log10space';
[ar_fl_saveborr_log10space] = ff_saveborr_grid(fl_a_min, fl_a_max, it_a_points, st_grid_type);
st_grid_type = 'grid_powerspace';
```









```
[ar_fl_saveborr_powerspace] = ff_saveborr_grid(f1_a_min, f1_a_max, it_a_points, st_grid_type);
st_grid_type = 'grid_evenlog';
[ar_fl_saveborr_evenlog] = ff_saveborr_grid(f1_a_min, f1_a_max, it_a_points, st_grid_type);
% draw four types of lines jointly
mt_value = [ar_fl_saveborr_linspace'; ar_fl_saveborr_log10space'; ...
    ar_fl_saveborr_powerspace'; ar_fl_saveborr_evenlog'];
ar_row_grid = ["grid linspace", "grid log10space", "grid powerspace", "grid evenlog"];
ar_col_grid = 1:it_a_points;
mp_support_graph = containers.Map('KeyType', 'char', 'ValueType', 'any');
mp_support_graph('cl_st_graph_title') = {'Four Asset Grids with Default Parameters'};
```

```

mp_support_graph('cl_st_ytitle') = {'Asset Grid Points'};
mp_support_graph('cl_st_xttitle') = {'Asset Grid Counter'};
mp_support_graph('bl_graph_logy') = true; % do not log
ff_graph_grid(mt_value, ar_row_grid, ar_col_grid, mp_support_graph);

```

8.1.3 Test FF_SAVEBORG_GRID Log Grid Changing Parameters

Log grid, same min and max, change log X1 and X2 points

```

% Same min and max and grid points
[fl_a_min, fl_a_max, it_a_points] = deal(0,50,25);
st_grid_type = 'grid_log10space';
% Four types of grid points
mp_grid_control = containers.Map('KeyType','char', 'ValueType','any');
mp_grid_control('grid_log10space_x1') = 0.1;
mp_grid_control('grid_log10space_x2') = 1;
[ar_fl_log10space_a] = ff_saveborr_grid(fl_a_min, fl_a_max, it_a_points, st_grid_type, mp_grid_contr
mp_grid_control('grid_log10space_x1') = 0.1/2;
mp_grid_control('grid_log10space_x2') = 1*2;
[ar_fl_log10space_b] = ff_saveborr_grid(fl_a_min, fl_a_max, it_a_points, st_grid_type, mp_grid_contr
mp_grid_control('grid_log10space_x1') = 0.1/4;
mp_grid_control('grid_log10space_x2') = 1*4;
[ar_fl_log10space_c] = ff_saveborr_grid(fl_a_min, fl_a_max, it_a_points, st_grid_type, mp_grid_contr
mp_grid_control('grid_log10space_x1') = 0.1/6;
mp_grid_control('grid_log10space_x2') = 1*6;
[ar_fl_log10space_d] = ff_saveborr_grid(fl_a_min, fl_a_max, it_a_points, st_grid_type, mp_grid_contr
% draw four types of lines jointly
mt_value = [ar_fl_log10space_a'; ar_fl_log10space_b'; ...
            ar_fl_log10space_c'; ar_fl_log10space_d'];
ar_row_grid = [...
    "log10space:x1=0.1/1, x2=1", ...
    "log10space:x1=0.1/2, x2=2", ...
    "log10space:x1=0.1/4, x2=3", ...
    "log10space:x1=0.1/6, x2=4"];
ar_col_grid = 1:it_a_points;
mp_support_graph = containers.Map('KeyType', 'char', 'ValueType', 'any');
mp_support_graph('cl_st_graph_title') = {'Asset Grids with Log 10 Grid Varying Controls'};
mp_support_graph('cl_st_ytitle') = {'Asset Grid Points'};
mp_support_graph('cl_st_xttitle') = {'Asset Grid Counter'};
mp_support_graph('bl_graph_logy') = true; % do not log
ff_graph_grid(mt_value, ar_row_grid, ar_col_grid, mp_support_graph);

```

8.1.4 Test FF_SAVEBORG_GRID Power Grid Changing Parameters

Log grid, same min and max, change log X1 and X2 points

```

% Same min and max and grid points
[fl_a_min, fl_a_max, it_a_points] = deal(0,50,25);
st_grid_type = 'grid_powerspace';
% Four types of grid points
mp_grid_control = containers.Map('KeyType','char', 'ValueType','any');
mp_grid_control('grid_powerspace_power') = 1;
[ar_fl_powerspace_a] = ff_saveborr_grid(fl_a_min, fl_a_max, it_a_points, st_grid_type, mp_grid_contr
mp_grid_control('grid_powerspace_power') = 2;
[ar_fl_powerspace_b] = ff_saveborr_grid(fl_a_min, fl_a_max, it_a_points, st_grid_type, mp_grid_contr
mp_grid_control('grid_powerspace_power') = 4;
[ar_fl_powerspace_c] = ff_saveborr_grid(fl_a_min, fl_a_max, it_a_points, st_grid_type, mp_grid_contr
mp_grid_control('grid_powerspace_power') = 6;
[ar_fl_powerspace_d] = ff_saveborr_grid(fl_a_min, fl_a_max, it_a_points, st_grid_type, mp_grid_contr

```

```
% draw four types of lines jointly
mt_value = [ar_fl_powerspace_a'; ar_fl_powerspace_b'; ...
            ar_fl_powerspace_c'; ar_fl_powerspace_d'];
ar_row_grid = [...;
    "powerspace:power=1", ...
    "powerspace:power=2", ...
    "powerspace:power=4", ...
    "powerspace:power=6"];
ar_col_grid = 1:it_a_points;
mp_support_graph = containers.Map('KeyType', 'char', 'ValueType', 'any');
mp_support_graph('cl_st_graph_title') = {'Asset Grids with Power Grid Varying Controls'};
mp_support_graph('cl_st_ytitle') = {'Asset Grid Points'};
mp_support_graph('cl_st_xtitle') = {'Asset Grid Counter'};
mp_support_graph('bl_graph_logy') = true; % do not log
ff_graph_grid(mt_value, ar_row_grid, ar_col_grid, mp_support_graph);
```

8.1.5 Test FF_SAVEBORR_GRID Threshold Grid Changing Parameters

Threshold Grid, Changing Threshold Levels. Initial segments below threshold are linspace, then logspace.

```
% Same min and max and grid points
[fl_a_min, fl_a_max, it_a_points] = deal(0,50,25);
st_grid_type = 'grid_evenlog';
% Four types of grid points
mp_grid_control = containers.Map('KeyType','char', 'ValueType','any');
mp_grid_control('grid_evenlog_threshold') = 0.50;
[ar_fl_evenlog_a] = ff_saveborr_grid(fl_a_min, fl_a_max, it_a_points, st_grid_type, mp_grid_control);
mp_grid_control('grid_evenlog_threshold') = 1.00;
[ar_fl_evenlog_b] = ff_saveborr_grid(fl_a_min, fl_a_max, it_a_points, st_grid_type, mp_grid_control);
mp_grid_control('grid_evenlog_threshold') = 2;
[ar_fl_evenlog_c] = ff_saveborr_grid(fl_a_min, fl_a_max, it_a_points, st_grid_type, mp_grid_control);
mp_grid_control('grid_evenlog_threshold') = 5;
[ar_fl_evenlog_d] = ff_saveborr_grid(fl_a_min, fl_a_max, it_a_points, st_grid_type, mp_grid_control);
% draw four types of lines jointly
mt_value = [ar_fl_evenlog_a'; ar_fl_evenlog_b'; ...
            ar_fl_evenlog_c'; ar_fl_evenlog_d'];
ar_row_grid = [...;
    "evenlog:threshold=0.5", ...
    "evenlog:threshold=1.0", ...
    "evenlog:threshold=2.0", ...
    "evenlog:threshold=5.0"];
ar_col_grid = 1:it_a_points;
mp_support_graph = containers.Map('KeyType', 'char', 'ValueType', 'any');
mp_support_graph('cl_st_graph_title') = {'Asset Grids with Threshold Grid Varying Controls'};
mp_support_graph('cl_st_ytitle') = {'Asset Grid Points'};
mp_support_graph('cl_st_xtitle') = {'Asset Grid Counter'};
mp_support_graph('bl_graph_logy') = true; % do not log
ff_graph_grid(mt_value, ar_row_grid, ar_col_grid, mp_support_graph);
```

Chapter 9

Common Functions

9.1 FFY_TAUCHEN AR1 Shock Discretization Example

Go back to fan's MEconTools Toolbox ([bookdown](#)), Matlab Code Examples Repository ([bookdown](#)), or Math for Econ with Matlab Repository ([bookdown](#)).

This is the example vignette for function: `ffy_tauchen` from the [MEconTools Package](#). : See also the `ffy_rouwenhorst` function from the [MEconTools Package](#). This function discretize a mean zero AR1 process, uses Tauchen (1986). See [AR 1 Example](#) for some details on how the AR1 process works. And See [Kopecky and Suen \(2010\)](#).

9.1.1 Test FFY_TAUCHEN Defaults

Call the function with defaults. Default sd bounds are plus and minus 4. This is used in the following examples, unless otherwise specified as the 5th parameter.

```
ffy_tauchen();  
-----  
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx  
CONTAINER NAME: mp_container_map ND Array (Matrix etc)  
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx  
      i   idx  ndim  numel  rowN  colN  sum  mean   std  coef  
      -   ---  ----  -----  ----  ----  ---  ---  ----  ----  
ar_disc_ar1      1     1     2      5      5     1     0     0  0.79057  
mt_disc_ar1_trans 2     6     2     25      5     5     5    0.2  0.27623  1.3  
  
xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxx  
      c1  
      ---  
      r1      -1  
      r2     -0.5  
      r3      0  
      r4     0.5  
      r5      1  
  
xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxxx  
      c1          c2          c3          c4          c5  
      -----  -----  -----  -----  -----  
      r1     0.22663     0.73331    0.040048  1.0689e-05  7.3923e-12  
      r2     0.012224    0.58648    0.39831   0.0029797   7.605e-08
```

```
r3    8.8417e-05      0.10556      0.7887      0.10556      8.8417e-05
r4    7.605e-08       0.0029797     0.39831     0.58648      0.012224
r5    7.3923e-12      1.0689e-05    0.040048    0.73331      0.22663
```

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

CONTAINER NAME: mp_container_map Scalars

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	value
	-	---	-----
fl_ar1_persistence	1	2	0.6
fl_ar1_step	2	3	0.5
fl_shk_std	3	4	0.2
it_std_bound	4	5	4

9.1.2 Test FFY_TAUCHEN Specify Parameters

With a grid of 10 points, the sd bounds on Tauchen and Rouwenhorst are identical. With the not extremely persistent shock process here, the Tauchen and Rouwenhorst Results are very similar.

```
[fl_ar1_persistence, fl_shk_std, it_disc_points, bl_verbose, it_std_bound] = ...
deal(0.60, 0.10, 10, true, 3);
ffy_tauchen(fl_ar1_persistence, fl_shk_std, it_disc_points, bl_verbose, it_std_bound);
```

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

CONTAINER NAME: mp_container_map ND Array (Matrix etc)

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	ndim	numel	rowN	colN	sum	mean
	-	---	----	-----	----	----	-----	-----
ar_disc_ar1	1	1	2	10	10	1	-7.2164e-16	-7.2164e-17
mt_disc_ar1_trans	2	6	2	100	10	10	10	0.1

xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxx

c1

r1	-0.375
r2	-0.29167
r3	-0.20833
r4	-0.125
r5	-0.041667
r6	0.041667
r7	0.125
r8	0.20833
r9	0.29167
r10	0.375

xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxx

c1

c2

c3

c4

c5

c6

c7

r1	0.13933	0.26196	0.31887	0.20154	0.066066	0.011201	0.0009785
r2	0.056673	0.16995	0.30658	0.28713	0.1396	0.035167	0.004575
r3	0.01861	0.087039	0.23281	0.32308	0.23281	0.087039	0.01684
r4	0.0048925	0.035167	0.1396	0.28713	0.30658	0.16995	0.04884
r5	0.0010235	0.011201	0.066066	0.20154	0.31887	0.26196	0.1116

r6	0.00016962	0.0028101	0.02466	0.11169	0.26196	0.31887	0.2015
r7	2.2197e-05	0.00055483	0.0072547	0.048841	0.16995	0.30658	0.2871
r8	2.2881e-06	8.6129e-05	0.0016806	0.016841	0.087039	0.23281	0.3230
r9	1.8543e-07	1.0503e-05	0.00030628	0.0045756	0.035167	0.1396	0.2871
r10	1.1798e-08	1.0053e-06	4.3874e-05	0.00097859	0.011201	0.066066	0.2015

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

CONTAINER NAME: mp_container_map Scalars

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	value
	-	---	-----
fl_ar1_persistence	1	2	0.6
fl_ar1_step	2	3	0.083333
fl_shk_std	3	4	0.1
it_std_bound	4	5	3

9.1.3 Test FFY_TAUCHEN High Persistence, Low SD

```
[fl_ar1_persistence, fl_shk_std, it_disc_points, bl_verbose] = ...
    deal(0.99, 0.01, 7, true);
ffy_tauchen(fl_ar1_persistence, fl_shk_std, it_disc_points, bl_verbose);
```

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

CONTAINER NAME: mp_container_map ND Array (Matrix etc)

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	ndim	numel	rowN	colN	sum	mean	std	c
	-	---	----	-----	----	----	---	-----	-----	-
ar_disc_ar1	1	1	2	7	7	1	0	0	0.15314	
mt_disc_ar1_trans	2	6	2	49	7	7	7	0.14286	0.35338	

xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxx

c1

r1	-0.21266
r2	-0.14178
r3	-0.070888
r4	0
r5	0.070888
r6	0.14178
r7	0.21266

xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxxx

c1

c2

c3

c4

c5

c6

	c1	c2	c3	c4	c5	c6
	-----	-----	-----	-----	-----	-----
r1	0.99957	0.00043152	0	0	0	0
r2	0.00011382	0.99955	0.0003337	0	0	0
r3	4.8683e-27	0.00015	0.99959	0.00025684	0	0
r4	1.4175e-70	1.0439e-26	0.00019675	0.99961	0.00019675	0
r5	1.9884e-135	4.986e-70	2.2273e-26	0.00025684	0.99959	0.00015
r6	1.2359e-221	1.149e-134	1.7451e-69	4.7287e-26	0.0003337	0.99955
r7	0	1.1738e-220	6.6059e-134	6.077e-69	9.9893e-26	0.00043152

```
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      i     idx    value
      -     ---   -----
fl_ar1_persistence  1     2      0.99
fl_ar1_step          2     3      0.070888
fl_shk_std           3     4      0.01
it_std_bound         4     5      3
```

9.1.4 Test FFY_TAUCHEN Low Persistence, Low SD

```
[fl_ar1_persistence, fl_shk_std, it_disc_points, bl_verbose] = ...
    deal(0.01, 0.01, 7, true);
ffy_tauchen(fl_ar1_persistence, fl_shk_std, it_disc_points, bl_verbose);
```

```
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      i     idx    ndim    numel   rowN   colN    sum       mean
      -     ---   ----   -----   ----   ----   -----   -----
ar_disc_ar1        1     1      2      7      7      1  3.4694e-18  4.9564e-19  0.
mt_disc_ar1_trans  2     6      2     49      7      7      7  0.14286  0.
```

```
xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxx
      c1
      -----

```

```
r1  -0.030002
r2  -0.020001
r3  -0.010001
r4   0
r5  0.010001
r6  0.020001
r7  0.030002
```

```
xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxxx
```

	c1	c2	c3	c4	c5	c6	c7
r1	0.0067533	0.064018	0.2484	0.38278	0.23505	0.057298	0.0057011
r2	0.0065668	0.06286	0.24618	0.38287	0.23728	0.05838	0.0058656
r3	0.0063849	0.061717	0.24396	0.38292	0.2395	0.059478	0.0060344
r4	0.0062075	0.06059	0.24173	0.38294	0.24173	0.06059	0.0062075
r5	0.0060344	0.059478	0.2395	0.38292	0.24396	0.061717	0.0063849
r6	0.0058656	0.05838	0.23728	0.38287	0.24618	0.06286	0.0065668
r7	0.0057011	0.057298	0.23505	0.38278	0.2484	0.064018	0.0067533

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

```
      i     idx    value
      -     ---   -----
```

fl_ar1_persistence	1	2	0.01
fl_ar1_step	2	3	0.010001
fl_shk_std	3	4	0.01
it_std_bound	4	5	3

9.1.5 Test FFY_TAUCHEN High Persistence, High SD

```
[fl_ar1_persistence, fl_shk_std, it_disc_points, bl_verbose] = ...
    deal(0.99, 0.99, 7, true);
ffy_tauchen(fl_ar1_persistence, fl_shk_std, it_disc_points, bl_verbose);
```

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	ndim	numel	rowN	colN	sum	mean
	-	---	----	-----	---	---	-----	-----
ar_disc_ar1	1	1	2	7	7	1	-7.1054e-15	-1.0151e-15
mt_disc_ar1_trans	2	6	2	49	7	7	7	0.14286

xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxx
c1

r1	-21.054
r2	-14.036
r3	-7.0179
r4	-1.7764e-15
r5	7.0179
r6	14.036
r7	21.054

xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6
	-----	-----	-----	-----	-----	-----
r1	0.99957	0.00043152	0	0	0	0
r2	0.00011382	0.99955	0.0003337	0	0	0
r3	4.8683e-27	0.00015	0.99959	0.00025684	0	0
r4	1.4175e-70	1.0439e-26	0.00019675	0.99961	0.00019675	0
r5	1.9884e-135	4.986e-70	2.2273e-26	0.00025684	0.99959	0.00015
r6	1.2359e-221	1.149e-134	1.7451e-69	4.7287e-26	0.0003337	0.99955
r7	0	1.1738e-220	6.6059e-134	6.077e-69	9.9893e-26	0.00043152

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	value
	-	---	-----
fl_ar1_persistence	1	2	0.99
fl_ar1_step	2	3	7.0179
fl_shk_std	3	4	0.99
it_std_bound	4	5	3

9.1.6 Test FFY_TAUCHEN Low Persistence, Low SD

```
[fl_ar1_persistence, fl_shk_std, it_disc_points, bl_verbose] = ...
    deal(0.01, 0.01, 7, true);
ffy_tauchen(fl_ar1_persistence, fl_shk_std, it_disc_points, bl_verbose);
```

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	ndim	numel	rowN	colN	sum	mean	
	-	---	----	-----	----	----	-----	-----	-----
ar_disc_ar1	1	1	2	7	7	1	3.4694e-18	4.9564e-19	0.
mt_disc_ar1_trans	2	6	2	49	7	7	7	0.14286	0.

xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxx
c1

	r1	r2	r3	r4	r5	r6	r7
	-0.030002	-0.020001	-0.010001	0	0.010001	0.020001	0.030002

xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6	c7
	-----	-----	-----	-----	-----	-----	-----
r1	0.0067533	0.064018	0.2484	0.38278	0.23505	0.057298	0.0057011
r2	0.0065668	0.06286	0.24618	0.38287	0.23728	0.05838	0.0058656
r3	0.0063849	0.061717	0.24396	0.38292	0.2395	0.059478	0.0060344
r4	0.0062075	0.06059	0.24173	0.38294	0.24173	0.06059	0.0062075
r5	0.0060344	0.059478	0.2395	0.38292	0.24396	0.061717	0.0063849
r6	0.0058656	0.05838	0.23728	0.38287	0.24618	0.06286	0.0065668
r7	0.0057011	0.057298	0.23505	0.38278	0.2484	0.064018	0.0067533

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

CONTAINER NAME: mp_container_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	value
	-	---	-----
fl_ar1_persistence	1	2	0.01
fl_ar1_step	2	3	0.010001
fl_shk_std	3	4	0.01
it_std_bound	4	5	3

9.2 FFY_ROUWENHORST AR1 Shock Discretization Example

Go back to fan's MEconTools Toolbox ([bookdown](#)), Matlab Code Examples Repository ([bookdown](#)), or Math for Econ with Matlab Repository ([bookdown](#)).

This is the example vignette for function: `ffy_rouwenhorst` from the **MEconTools Package**. See also `ffy_tauchen` function from the **MEconTools Package**. This function discretize a mean zero AR1 process, uses Rouwenhorst (1995). See [AR 1 Example](#) for some details on how the AR1 process works. And See [Kopecky and Suen \(2010\)](#).

9.2.1 Test FFY_ROUWENHORST Defaults

Call the function with defaults.

```
ffy_rouwenhorst();
```

```
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      i   idx  ndim  numel  rowN  colN  sum  mean   std   coef
      -   ---  ----  -----  ----  ----  ---  ---  ----  -----
ar_disc_ar1       1     1     2      5      5     1     0     0  0.39528
mt_disc_ar1_trans 2    11     2     25      5     5     5   0.2  0.18246  0.91
xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxx
      c1
      -----
r1    -0.5
r2    -0.25
r3     0
r4    0.25
r5    0.5

xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxxx
      c1      c2      c3      c4      c5
      -----  -----
r1    0.4096   0.4096   0.1536   0.0256   0.0016
r2    0.1024   0.4864   0.3264   0.0784   0.0064
r3    0.0256   0.2176   0.5136   0.2176   0.0256
r4    0.0064   0.0784   0.3264   0.4864   0.1024
r5    0.0016   0.0256   0.1536   0.4096   0.4096

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      i   idx  value
      -   ---  -----
fl_ar1_beg        1     2    -0.5
fl_ar1_end        2     3     0.5
fl_ar1_persistence 3     4     0.6
fl_ar1_step       4     5    0.25
fl_p0             5     6     0.8
fl_q0             6     7     0.8
fl_shk_std        7     8     0.2
fl_sig_ar1        8     9    0.25
it_std_bound      9    10      0
```

9.2.2 Test FFY_ROUWENHORST Specify Parameters

With a grid of 10 points, the Rouwenhorst bounds on standard deviations are equal to Tauchen bounds of 3. With the not extremely persistent shock process here, the Tauchen and Rouwenhorst Results are very similar.

```
[f1_ar1_persistence, f1_shk_std, it_disc_points, bl_verbose] = ...
    deal(0.60, 0.10, 10, true);
ffy_rouwenhorst(f1_ar1_persistence, f1_shk_std, it_disc_points, bl_verbose);

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

      i   idx  ndim  numel  rowN  colN  sum  mean
      -   ---  ----  -----  ----  ----  -----  -----
ar_disc_ar1      1     1     2      10     10      1  5.5511e-17  5.5511e-18  0.
mt_disc_ar1_trans  2    11     2     100     10     10      10      0.1  0.

xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxx
      c1
      -----
r1      -0.375
r2      -0.29167
r3      -0.20833
r4      -0.125
r5      -0.041667
r6      0.041667
r7      0.125
r8      0.20833
r9      0.29167
r10     0.375

xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxxx
      c1      c2      c3      c4      c5      c6      c7
      -----  -----
r1      0.13422  0.30199  0.30199  0.17616  0.06606  0.016515  0.0027525
r2      0.033554 0.20133  0.32716  0.26424  0.12662  0.038535  0.0075694
r3      0.0083886 0.081789 0.26267  0.32755  0.21401  0.082747  0.019741
r4      0.0020972 0.028312 0.14038  0.30946  0.30369  0.15877  0.047989
r5      0.00052429 0.009044 0.061145 0.20246  0.33477  0.25969  0.10585
r6      0.00013107 0.0027525 0.023642 0.10585  0.25969  0.33477  0.20246
r7      3.2768e-05 0.00081101 0.0084603 0.047989 0.15877  0.30369  0.30946
r8      8.192e-06  0.00023347 0.0028677 0.019741 0.082747 0.21401  0.32755
r9      2.048e-06  6.6048e-05 0.00093389 0.0075694 0.038535 0.12662  0.26424
r10     5.12e-07  1.8432e-05 0.00029491 0.0027525 0.016515 0.06606  0.17616

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

      i   idx  value
      -   ---  -----
f1_ar1_beg      1     2    -0.375
f1_ar1_end      2     3     0.375
```

fl_ar1_persistence	3	4	0.6
fl_ar1_step	4	5	0.083333
fl_p0	5	6	0.8
fl_q0	6	7	0.8
fl_shk_std	7	8	0.1
fl_sig_ar1	8	9	0.125
it_std_bound	9	10	0

9.2.3 Test FFY_ROUWENHORST High Persistence, Low SD

```
[fl_ar1_persistence, fl_shk_std, it_disc_points, bl_verbose] = ...
    deal(0.90, 0.02, 7, true);
[ar_z, mt_z_trans] = ffy_tauchen(fl_ar1_persistence, fl_shk_std, it_disc_points, bl_verbose);

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

      i      idx     ndim    numel   rowN   colN     sum   mean
      -      ---     ----    -----   ----   ----   -----   -----
ar_disc_ar1      1       1       2       7       7       1  2.7756e-17  3.9651e-18  0.
mt_disc_ar1_trans 2       6       2      49       7       7          7  0.14286   0

xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxx
      c1
      -----
r1      -0.13765
r2      -0.091766
r3      -0.045883
r4      1.3878e-17
r5      0.045883
r6      0.091766
r7      0.13765

xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxxx
      c1      c2      c3      c4      c5      c6      c7
      -----
r1      0.67682  0.32022  0.0029525  2.2423e-07  1.058e-13  0
r2      0.054147  0.7002   0.24422   0.0014299  6.5815e-08  1.8541e-14
r3      0.00012097 0.084213  0.73627   0.17874   0.00065947  1.8356e-08  3.1086
r4      4.8643e-09 0.00028953  0.12539   0.74865   0.12539   0.00028953  4.8643
r5      3.0921e-15 1.8356e-08  0.00065947  0.17874   0.73627   0.084213  0.0001
r6      2.9554e-23 1.8558e-14  6.5815e-08  0.0014299  0.24422   0.7002   0.05
r7      4.1477e-33 2.8319e-22  1.0576e-13  2.2423e-07  0.0029525  0.32022  0.6

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

      i      idx     value
      -      ---   -----
fl_ar1_persistence 1       2       0.9
fl_ar1_step        2       3       0.045883
fl_shk_std         3       4       0.02
```

```

it_std_bound          4      5          3

ar_z_stationary = mt_z_trans^1000;
ar_z_stationary = ar_z_stationary(1,:);
fl_labor_agg = ar_z_stationary*exp(ar_z);
ar_z = exp(ar_z')/fl_labor_agg;

```

9.2.4 Test FFY_ROUWENHORST Low Persistence, Low SD

```

[fl_ar1_persistence, fl_shk_std, it_disc_points, bl_verbose] = ...
    deal(0.01, 0.01, 7, true);
ffy_rouwenhorst(fl_ar1_persistence, fl_shk_std, it_disc_points, bl_verbose);

```

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	ndim	numel	rowN	colN	sum	mean	std
	-	---	----	-----	----	----	---	-----	-----
ar_disc_ar1	1	1	2	7	7	1	0	0	0.017639
mt_disc_ar1_trans	2	11	2	49	7	7	7	0.14286	0.10985

xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxx
c1

r1	-0.024496
r2	-0.016331
r3	-0.0081654
r4	0
r5	0.0081654
r6	0.016331
r7	0.024496

xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxxx

c1	c2	c3	c4	c5	c6	c7	
-----	-----	-----	-----	-----	-----	-----	
r1	0.016586	0.097547	0.23904	0.31241	0.22966	0.090047	0.014711
r2	0.016258	0.096266	0.23749	0.31247	0.23124	0.091266	0.015008
r3	0.015936	0.094997	0.23594	0.31251	0.23281	0.092497	0.015311
r4	0.01562	0.093741	0.23438	0.31252	0.23438	0.093741	0.01562
r5	0.015311	0.092497	0.23281	0.31251	0.23594	0.094997	0.015936
r6	0.015008	0.091266	0.23124	0.31247	0.23749	0.096266	0.016258
r7	0.014711	0.090047	0.22966	0.31241	0.23904	0.097547	0.016586

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

CONTAINER NAME: mp_container_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

i	idx	value	
-	---	-----	
fl_ar1_beg	1	2	-0.024496
fl_ar1_end	2	3	0.024496
fl_ar1_persistence	3	4	0.01
fl_ar1_step	4	5	0.0081654

fl_p0	5	6	0.505
fl_q0	6	7	0.505
fl_shk_std	7	8	0.01
fl_sig_ar1	8	9	0.010001
it_std_bound	9	10	0

9.2.5 Test FFY_ROUWENHORST High Persistence, High SD

```
[fl_ar1_persistence, fl_shk_std, it_disc_points, bl_verbose] = ...
    deal(0.99, 0.99, 7, true);
ffy_rouwenhorst(fl_ar1_persistence, fl_shk_std, it_disc_points, bl_verbose);
```

```
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      i   idx  ndim  numel  rowN  colN  sum  mean
      -   ---  ----  -----  ----  ----  -----  -----
ar_disc_ar1      1     1     2      7      7      1  3.5527e-15  5.0753e-16  1
mt_disc_ar1_trans 2    11     2     49      7      7          7  0.14286  0.
```

```
xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxx
      c1
      -----

```

r1	-17.19
r2	-11.46
r3	-5.7301
r4	0
r5	5.7301
r6	11.46
r7	17.19

```
xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxxx
```

	c1	c2	c3	c4	c5	c6	c7
	-----	-----	-----	-----	-----	-----	-----
r1	0.97037	0.029257	0.00036756	2.4627e-06	9.2815e-09	1.8656e-11	1.5625
r2	0.0048762	0.9705	0.024382	0.00024504	1.2314e-06	3.0938e-09	3.1094
r3	2.4504e-05	0.009753	0.97057	0.019506	0.00014703	4.9254e-07	6.1877
r4	1.2313e-07	7.3513e-05	0.01463	0.97059	0.01463	7.3513e-05	1.2313
r5	6.1877e-10	4.9254e-07	0.00014703	0.019506	0.97057	0.009753	2.4504
r6	3.1094e-12	3.0938e-09	1.2314e-06	0.00024504	0.024382	0.9705	0.004
r7	1.5625e-14	1.8656e-11	9.2815e-09	2.4627e-06	0.00036756	0.029257	0.9

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

```
CONTAINER NAME: mp_container_map Scalars
```

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	value
	-	---	-----
fl_ar1_beg	1	2	-17.19
fl_ar1_end	2	3	17.19
fl_ar1_persistence	3	4	0.99
fl_ar1_step	4	5	5.7301
fl_p0	5	6	0.995

fl_q0	6	7	0.995
fl_shk_std	7	8	0.99
fl_sig_ar1	8	9	7.0179
it_std_bound	9	10	0

9.2.6 Test FFY_ROUWENHORST Low Persistence, Low SD

```
[fl_ar1_persistence, fl_shk_std, it_disc_points, bl_verbose] = ...
    deal(0.01, 0.01, 7, true);
ffy_rouwenhorst(fl_ar1_persistence, fl_shk_std, it_disc_points, bl_verbose);

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

      i   idx  ndim  numel  rowN  colN  sum  mean  std
      -   ---  ----  -----  ----  ----  ---  -----  -----
ar_disc_ar1      1     1     2      7      7      1      0      0  0.017639
mt_disc_ar1_trans 2    11     2     49      7      7      7  0.14286  0.10985

xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxx
      c1
      -----
r1  -0.024496
r2  -0.016331
r3  -0.0081654
r4   0
r5  0.0081654
r6  0.016331
r7  0.024496

xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxxx
      c1      c2      c3      c4      c5      c6      c7
      -----  -----  -----  -----  -----  -----  -----
r1  0.016586  0.097547  0.23904  0.31241  0.22966  0.090047  0.014711
r2  0.016258  0.096266  0.23749  0.31247  0.23124  0.091266  0.015008
r3  0.015936  0.094997  0.23594  0.31251  0.23281  0.092497  0.015311
r4  0.01562  0.093741  0.23438  0.31252  0.23438  0.093741  0.01562
r5  0.015311  0.092497  0.23281  0.31251  0.23594  0.094997  0.015936
r6  0.015008  0.091266  0.23124  0.31247  0.23749  0.096266  0.016258
r7  0.014711  0.090047  0.22966  0.31241  0.23904  0.097547  0.016586

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

      i   idx  value
      -   ---  -----
fl_ar1_beg      1     2  -0.024496
fl_ar1_end      2     3   0.024496
fl_ar1_persistence  3     4   0.01
fl_ar1_step      4     5  0.0081654
fl_p0            5     6   0.505
fl_q0            6     7   0.505
```

fl_shk_std	7	8	0.01
fl_sig_ar1	8	9	0.010001
it_std_bound	9	10	0

Chapter 10

System

10.1 FF_FIND_FILES Examples

Go back to fan's MEconTools Toolbox ([bookdown](#)), Matlab Code Examples Repository ([bookdown](#)), or Math for Econ with Matlab Repository ([bookdown](#)).

This is the example vignette for function: `ff_find_files` from the **MEconTools Package**. This function finds files in subfolders of folders.

10.1.1 Test FF_FIND_FILES Defaults

Call the function with defaults.

```
[cl_st_file_names, cl_st_folder_names] = ff_find_files();
disp(cl_st_file_names);

'ff_az_vf_vecsv.m'      'ff_ipwkz_vf_vecsv.m'

disp(cl_st_folder_names);

'c:\Users\fan\CodeDynaAsset\m_az\solve'      'c:\Users\fan\CodeDynaAsset\m_ipwkz\solve'
```

10.1.2 Test FF_FIND_FILES search for files in subfolders

Search for .mlx files in two subfolders:

```
st_proj_folder = 'C:\Users\fan\MEconTools\MEconTools\doc\' ;
cl_st_subfolder = {'generate','vfi'} ;
st_file_search_name = '*.mlx' ;
bl_verbose = true ;
[cl_st_file_names, cl_st_folder_names] = ff_find_files(... 
    st_proj_folder, cl_st_subfolder, st_file_search_name, bl_verbose) ;

C:\Users\fan\MEconTools\MEconTools\doc\generate\*.mlx
fx_saveborr_grid.mlx
C:\Users\fan\MEconTools\MEconTools\doc\generate
C:\Users\fan\MEconTools\MEconTools\doc\vfi\*.mlx
fx_vfi_az_bisec_loop.mlx
C:\Users\fan\MEconTools\MEconTools\doc\vfi
fx_vfi_az_bisec_vec.mlx
C:\Users\fan\MEconTools\MEconTools\doc\vfi
fx_vfi_az_loop.mlx
C:\Users\fan\MEconTools\MEconTools\doc\vfi
fx_vfi_az_mzoom_loop.mlx
```

```
C:\Users\fan\MEconTools\MEconTools\doc\vfi
fx_vfi_az_mzoom_vec.mlx
C:\Users\fan\MEconTools\MEconTools\doc\vfi
fx_vfi_az_vec.mlx
C:\Users\fan\MEconTools\MEconTools\doc\vfi
```

10.2 FF_MLX2HTMLPDF_RUNANDEXPORT Examples

Go back to fan's MEconTools Toolbox ([bookdown](#)), Matlab Code Examples Repository ([bookdown](#)), or Math for Econ with Matlab Repository ([bookdown](#)).

This is the example vignette for function: [ff_mlx2htmlpdf_runandexport](#) from the [MEconTools Package](#). This file runs MLX files and converts it to HTML files.

10.2.1 Test FF_MLX2HTMLPDF_RUNANDEXPORT search for MLX files and Convert to HTML

Finds MLX files, re-run, and save to HTML in possibly another folder.

```
st_proj_folder = 'C:\Users\fan\MEconTools\MEconTools\doc\' ;
cl_st_subfolder = {'generate','graph'} ;
st_out_folder = 'C:\Users\fan\MEconTools\MEconTools\doc\sys\_test' ;
st_mlx_search_name = '*.mlx' ;
st_pub_format = 'html' ;
bl_run_mlx = true ;
bl_run_mlx_only = false ;
bl_verbose = true ;
ff_mlx2htmlpdf_runandexport(
    st_proj_folder, cl_st_subfolder, ...
    st_mlx_search_name, st_out_folder, st_pub_format, ...
    bl_run_mlx, bl_run_mlx_only, ...
    bl_verbose) ;

execute:fx_saveborr_grid.mlx
-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      i     idx    ndim   numel   rowN   colN     sum   mean    std   coe
      -     ---    ----   -----   ----   ----   -----   -----   -----   -----
ar_fl_saveborr    1      1      2      25      25      1    385.93  15.437  15.324  0.9
      r1      1
      r2    1.0174
      r3    1.0982
      r4    1.2707
      r5    1.5557
      r6    1.9707
      r7    2.5312
      r8    3.2512
      r9    4.1434
      r10   5.2196
      r11   6.4912
      r12   7.9687
```

```

r13      9.6621
r14     11.581
r15     13.735
r16     16.132
r17     18.781
r18     21.691
r19     24.87
r20     28.324
r21     32.063
r22     36.093
r23     40.421
r24     45.054
r25      50
-----
```

```

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	value
	-	---	-----
grid_evenlog_threshold	1	2	1
grid_log10space_x1	2	3	0.3
grid_log10space_x2	3	4	3
grid_powerspace_power	4	5	2.5

10.2.2 Test FF_MLX2HTMLPDF_RUNANDEXPORT re-run MLX

Finds MLX files, re-run, do NOT save HTML.

```

st_proj_folder = 'C:\Users\fan\MEconTools\MEconTools\doc\' ;
cl_st_subfolder = {'external'} ;
st_mlx_search_name = '*.mlx' ;
st_out_folder = '' ;
st_pub_format = '' ;
bl_run_mlx = true ;
bl_run_mlx_only = true ;
bl_verbose = true ;
ff_mlx2htmlpdf_runandexport...
    st_proj_folder, cl_st_subfolder, ...
    st_mlx_search_name, st_out_folder, st_pub_format, ...
    bl_run_mlx, bl_run_mlx_only, ...
    bl_verbose) ;
```

```

-----
```

```

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

```

CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coef
	-	---	----	-----	----	----	---	----	-----	-----
ar_disc_ar1	1	1	2	5	5	1	0	0	0.39528	
mt_disc_ar1_trans	2	11	2	25	5	5	5	0.2	0.18246	0.91

```

xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxx
```

```

    c1
```

```

-----
```

```

    r1      -0.5
```

```

r2      -0.25
r3       0
r4      0.25
r5      0.5

xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxxxx
      c1      c2      c3      c4      c5
      -----  -----
r1    0.4096   0.4096   0.1536   0.0256   0.0016
r2    0.1024   0.4864   0.3264   0.0784   0.0064
r3    0.0256   0.2176   0.5136   0.2176   0.0256
r4    0.0064   0.0784   0.3264   0.4864   0.1024
r5    0.0016   0.0256   0.1536   0.4096   0.4096
      -----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      i      idx     value
      -      ---  -----
fl_ar1_beg        1      2     -0.5
fl_ar1_end        2      3      0.5
fl_ar1_persistence 3      4      0.6
fl_ar1_step       4      5      0.25
fl_p0             5      6      0.8
fl_q0             6      7      0.8
fl_shk_std        7      8      0.2
fl_sig_ar1        8      9      0.25
it_std_bound      9     10      0
      -----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      i      idx     ndim    numel   rowN   colN     sum   mean
      -      ---  -----  -----  -----  -----  -----  -----
ar_disc_ar1       1      1      2      10     10      1  5.5511e-17  5.5511e-18  0
mt_disc_ar1_trans 2     11      2     100     10     10      10      0.1      0.1
      -----
xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxx
      c1
      -----
r1      -0.375
r2     -0.29167
r3     -0.20833
r4      -0.125
r5     -0.041667
r6      0.041667
r7      0.125
r8      0.20833
r9      0.29167
r10     0.375

xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxxx

```

	c1	c2	c3	c4	c5	c6	c7	
	-----	-----	-----	-----	-----	-----	-----	
r1	0.13422	0.30199	0.30199	0.17616	0.06606	0.016515	0.0027525	
r2	0.033554	0.20133	0.32716	0.26424	0.12662	0.038535	0.0075694	
r3	0.0083886	0.081789	0.26267	0.32755	0.21401	0.082747	0.019741	
r4	0.0020972	0.028312	0.14038	0.30946	0.30369	0.15877	0.047989	
r5	0.00052429	0.009044	0.061145	0.20246	0.33477	0.25969	0.10585	
r6	0.00013107	0.0027525	0.023642	0.10585	0.25969	0.33477	0.20246	
r7	3.2768e-05	0.00081101	0.0084603	0.047989	0.15877	0.30369	0.30946	
r8	8.192e-06	0.00023347	0.0028677	0.019741	0.082747	0.21401	0.32755	
r9	2.048e-06	6.6048e-05	0.00093389	0.0075694	0.038535	0.12662	0.26424	
r10	5.12e-07	1.8432e-05	0.00029491	0.0027525	0.016515	0.06606	0.17616	
<hr/>								
xx								
CONTAINER NAME: mp_container_map Scalars								
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx								
	i	idx	value					
	-	---	-----					
fl_ar1_beg	1	2	-0.375					
fl_ar1_end	2	3	0.375					
fl_ar1_persistence	3	4	0.6					
fl_ar1_step	4	5	0.083333					
fl_p0	5	6	0.8					
fl_q0	6	7	0.8					
fl_shk_std	7	8	0.1					
fl_sig_ar1	8	9	0.125					
it_std_bound	9	10	0					
<hr/>								
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx								
CONTAINER NAME: mp_container_map ND Array (Matrix etc)								
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx								
	i	idx	ndim	numel	rowN	colN	sum	mean
	-	---	---	-----	---	---	-----	-----
ar_disc_ar1	1	1	2	7	7	1	2.7756e-17	3.9651e-18
mt_disc_ar1_trans	2	6	2	49	7	7	7	0.14286
<hr/>								
xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxx								
c1								
<hr/>								
r1	-0.13765							
r2	-0.091766							
r3	-0.045883							
r4	1.3878e-17							
r5	0.045883							
r6	0.091766							
r7	0.13765							
<hr/>								
xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxxx								
	c1	c2	c3	c4	c5	c6	c7	
	-----	-----	-----	-----	-----	-----	-----	
r1	0.67682	0.32022	0.0029525	2.2423e-07	1.058e-13		0	

r2	0.054147	0.7002	0.24422	0.0014299	6.5815e-08	1.8541e-14
r3	0.00012097	0.084213	0.73627	0.17874	0.00065947	1.8356e-08
r4	4.8643e-09	0.00028953	0.12539	0.74865	0.12539	0.00028953
r5	3.0921e-15	1.8356e-08	0.00065947	0.17874	0.73627	0.084213
r6	2.9554e-23	1.8558e-14	6.5815e-08	0.0014299	0.24422	0.7002
r7	4.1477e-33	2.8319e-22	1.0576e-13	2.2423e-07	0.0029525	0.32022

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

i	idx	value
-	---	-----
fl_ar1_persistence	1	2
fl_ar1_step	2	3
fl_shk_std	3	4
it_std_bound	4	5
		3

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

i	idx	ndim	numel	rowN	colN	sum	mean	std
-	---	----	-----	----	----	---	-----	-----
ar_disc_ar1	1	1	2	7	7	1	0	0.017639
mt_disc_ar1_trans	2	11	2	49	7	7	0.14286	0.10985

xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxx
c1

r1	-0.024496
r2	-0.016331
r3	-0.0081654
r4	0
r5	0.0081654
r6	0.016331
r7	0.024496

xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxxx

c1	c2	c3	c4	c5	c6	c7
-----	-----	-----	-----	-----	-----	-----
r1	0.016586	0.097547	0.23904	0.31241	0.22966	0.090047
r2	0.016258	0.096266	0.23749	0.31247	0.23124	0.091266
r3	0.015936	0.094997	0.23594	0.31251	0.23281	0.092497
r4	0.01562	0.093741	0.23438	0.31252	0.23438	0.093741
r5	0.015311	0.092497	0.23281	0.31251	0.23594	0.094997
r6	0.015008	0.091266	0.23124	0.31247	0.23749	0.096266
r7	0.014711	0.090047	0.22966	0.31241	0.23904	0.097547

```
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

i	idx	value
---	-----	-------

```

      -  ---  -----
fl_ar1_beg      1    2   -0.024496
fl_ar1_end      2    3    0.024496
fl_ar1_persistence 3    4     0.01
fl_ar1_step      4    5   0.0081654
fl_p0            5    6     0.505
fl_q0            6    7     0.505
fl_shk_std       7    8     0.01
fl_sig_ar1       8    9   0.010001
it_std_bound     9   10     0

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      i   idx  ndim  numel  rowN  colN  sum  mean
      -  ---  ----  -----  ----  ----  -----  -----
ar_disc_ar1     1    1     2     7     7     1  3.5527e-15  5.0753e-16  1
mt_disc_ar1_trans 2   11     2    49     7     7     7  0.14286  0.

xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxx
      c1
      -----
r1    -17.19
r2    -11.46
r3    -5.7301
r4      0
r5    5.7301
r6    11.46
r7    17.19

xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxxx
      c1        c2        c3        c4        c5        c6        c7
      -----  -----
r1    0.97037  0.029257  0.00036756  2.4627e-06  9.2815e-09  1.8656e-11  1.5625
r2    0.0048762  0.9705   0.024382  0.00024504  1.2314e-06  3.0938e-09  3.1094
r3    2.4504e-05  0.009753  0.97057   0.019506  0.00014703  4.9254e-07  6.1877
r4    1.2313e-07  7.3513e-05  0.01463   0.97059   0.01463   7.3513e-05  1.2313
r5    6.1877e-10  4.9254e-07  0.00014703  0.019506  0.97057   0.009753  2.4504
r6    3.1094e-12  3.0938e-09  1.2314e-06  0.00024504  0.024382   0.9705  0.004
r7    1.5625e-14  1.8656e-11  9.2815e-09  2.4627e-06  0.00036756  0.029257  0.9

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      i   idx  value
      -  ---  -----
fl_ar1_beg      1    2   -17.19
fl_ar1_end      2    3    17.19
fl_ar1_persistence 3    4     0.99
fl_ar1_step      4    5    5.7301
fl_p0            5    6    0.995

```

```

fl_q0          6    7      0.995
fl_shk_std    7    8      0.99
fl_sig_ar1    8    9      7.0179
it_std_bound  9   10      0

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
                                         i     idx    ndim   numel   rowN   colN   sum   mean   std
                                         -     ---    ----  -----  ----  ----  ---  -----  -----
ar_disc_ar1    1     1      2       7      7      1      0      0  0.017639
mt_disc_ar1_trans 2    11      2      49      7      7      7  0.14286  0.10985

xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxx
      c1
      -----
r1    -0.024496
r2    -0.016331
r3    -0.0081654
r4      0
r5    0.0081654
r6    0.016331
r7    0.024496

xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxxx
      c1      c2      c3      c4      c5      c6      c7
      -----  -----  -----  -----  -----  -----  -----
r1    0.016586  0.097547  0.23904  0.31241  0.22966  0.090047  0.014711
r2    0.016258  0.096266  0.23749  0.31247  0.23124  0.091266  0.015008
r3    0.015936  0.094997  0.23594  0.31251  0.23281  0.092497  0.015311
r4    0.01562   0.093741  0.23438  0.31252  0.23438  0.093741  0.01562
r5    0.015311  0.092497  0.23281  0.31251  0.23594  0.094997  0.015936
r6    0.015008  0.091266  0.23124  0.31247  0.23749  0.096266  0.016258
r7    0.014711  0.090047  0.22966  0.31241  0.23904  0.097547  0.016586

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
                                         i     idx    value
                                         -     ---  -----
fl_ar1_beg    1     2      -0.024496
fl_ar1_end    2     3      0.024496
fl_ar1_persistence 3     4      0.01
fl_ar1_step   4     5      0.0081654
fl_p0         5     6      0.505
fl_q0         6     7      0.505
fl_shk_std   7     8      0.01
fl_sig_ar1   8     9      0.010001
it_std_bound  9    10      0

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

```

CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coef
	-	---	----	-----	----	----	---	---	-----	-----
ar_disc_ar1	1	1	2	5	5	1	0	0	0.79057	
mt_disc_ar1_trans	2	6	2	25	5	5	5	0.2	0.27623	1.3

xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxxxxx
c1

r1 -1
r2 -0.5
r3 0
r4 0.5
r5 1

xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxx
c1 c2 c3 c4 c5
----- ----- ----- ----- -----
r1 0.22663 0.73331 0.040048 1.0689e-05 7.3923e-12
r2 0.012224 0.58648 0.39831 0.0029797 7.605e-08
r3 8.8417e-05 0.10556 0.7887 0.10556 8.8417e-05
r4 7.605e-08 0.0029797 0.39831 0.58648 0.012224
r5 7.3923e-12 1.0689e-05 0.040048 0.73331 0.22663

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	value
	-	---	-----
fl_ar1_persistence	1	2	0.6
fl_ar1_step	2	3	0.5
fl_shk_std	3	4	0.2
it_std_bound	4	5	4

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	ndim	numel	rowN	colN	sum	mean
	-	---	----	-----	----	----	-----	-----
ar_disc_ar1	1	1	2	10	10	1	-7.2164e-16	-7.2164e-17
mt_disc_ar1_trans	2	6	2	100	10	10	10	0.1

xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxx
c1

r1 -0.375
r2 -0.29167
r3 -0.20833
r4 -0.125

```

r5      -0.041667
r6      0.041667
r7      0.125
r8      0.20833
r9      0.29167
r10     0.375

xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxxxx
      c1        c2        c3        c4        c5        c6        c7
      -----      -----      -----      -----      -----      -----
r1      0.13933   0.26196   0.31887   0.20154   0.066066  0.011201  0.0009785
r2      0.056673  0.16995   0.30658   0.28713   0.1396    0.035167  0.004575
r3      0.01861   0.087039  0.23281   0.32308   0.23281   0.087039  0.01684
r4      0.0048925 0.035167  0.1396    0.28713   0.30658   0.16995   0.04884
r5      0.0010235 0.011201  0.066066  0.20154   0.31887   0.26196   0.1116
r6      0.00016962 0.0028101 0.02466   0.11169   0.26196   0.31887   0.2015
r7      2.2197e-05 0.00055483 0.0072547 0.048841  0.16995   0.30658   0.2871
r8      2.2881e-06 8.6129e-05 0.0016806  0.016841  0.087039  0.23281   0.3230
r9      1.8543e-07 1.0503e-05 0.00030628 0.0045756 0.035167  0.1396    0.2871
r10     1.1798e-08 1.0053e-06 4.3874e-05 0.00097859 0.011201  0.066066  0.2015

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      i      idx      value
      -      ---      -----
fl_ar1_persistence 1      2      0.6
fl_ar1_step        2      3      0.083333
fl_shk_std         3      4      0.1
it_std_bound       4      5      3

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
      i      idx      ndim      numel      rowN      colN      sum      mean      std      c
      -      ---      ----      -----      ----      ----      ---      ---      ----      -
ar_disc_ar1        1      1      2      7      7      1      0      0      0.15314
mt_disc_ar1_trans 2      6      2      49      7      7      7      0.14286  0.35338

xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxx
      c1
      -----
r1      -0.21266
r2      -0.14178
r3      -0.070888
r4      0
r5      0.070888
r6      0.14178
r7      0.21266

xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxxx
      c1        c2        c3        c4        c5        c6
      -----      -----      -----      -----      -----      -----

```

```

-----
r1      0.99957   0.00043152       0       0       0       0       0
r2      0.00011382  0.99955    0.0003337       0       0       0       0
r3      4.8683e-27  0.00015    0.99959    0.00025684       0       0       0
r4      1.4175e-70  1.0439e-26  0.00019675  0.99961   0.00019675       0
r5      1.9884e-135 4.986e-70   2.2273e-26  0.00025684  0.99959   0.00015
r6      1.2359e-221 1.149e-134  1.7451e-69   4.7287e-26  0.0003337  0.99955
r7          0     1.1738e-220  6.6059e-134  6.077e-69   9.9893e-26  0.00043152  0.0

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

      i      idx      value
      -      ---      -----
f1_ar1_persistence  1      2      0.99
f1_ar1_step        2      3      0.070888
f1_shk_std         3      4      0.01
it_std_bound       4      5      3

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

      i      idx      ndim      numel      rowN      colN      sum      mean
      -      ---      ----      -----      ----      ----      -----      -----
ar_disc_ar1        1      1      2      7      7      1      3.4694e-18  4.9564e-19
mt_disc_ar1_trans  2      6      2      49      7      7      7      0.14286   0.0

xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxx
      c1
      -----
r1      -0.030002
r2      -0.020001
r3      -0.010001
r4          0
r5      0.010001
r6      0.020001
r7      0.030002

xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxxx
      c1      c2      c3      c4      c5      c6      c7
      -----
r1      0.0067533  0.064018  0.2484  0.38278  0.23505  0.057298  0.0057011
r2      0.0065668  0.06286  0.24618  0.38287  0.23728  0.05838  0.0058656
r3      0.0063849  0.061717  0.24396  0.38292  0.2395  0.059478  0.0060344
r4      0.0062075  0.06059  0.24173  0.38294  0.24173  0.06059  0.0062075
r5      0.0060344  0.059478  0.2395  0.38292  0.24396  0.061717  0.0063849
r6      0.0058656  0.05838  0.23728  0.38287  0.24618  0.06286  0.0065668
r7      0.0057011  0.057298  0.23505  0.38278  0.2484  0.064018  0.0067533

-----
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

```

CONTAINER NAME: mp_container_map Scalars

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	value
	-	---	-----
fl_ar1_persistence	1	2	0.01
fl_ar1_step	2	3	0.010001
fl_shk_std	3	4	0.01
it_std_bound	4	5	3

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

CONTAINER NAME: mp_container_map ND Array (Matrix etc)

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	ndim	numel	rowN	colN	sum	mean
	-	---	----	-----	----	----	-----	-----
ar_disc_ar1	1	1	2	7	7	1	-7.1054e-15	-1.0151e-15
mt_disc_ar1_trans	2	6	2	49	7	7	7	0.14286

xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxx

c1

r1	-21.054
r2	-14.036
r3	-7.0179
r4	-1.7764e-15
r5	7.0179
r6	14.036
r7	21.054

xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxxx

c1

c2

c3

c4

c5

c6

r1	0.99957	0.00043152	0	0	0	0	0
r2	0.00011382	0.99955	0.0003337	0	0	0	0
r3	4.8683e-27	0.00015	0.99959	0.00025684	0	0	0
r4	1.4175e-70	1.0439e-26	0.00019675	0.99961	0.00019675	0	0
r5	1.9884e-135	4.986e-70	2.2273e-26	0.00025684	0.99959	0.00015	0.00015
r6	1.2359e-221	1.149e-134	1.7451e-69	4.7287e-26	0.0003337	0.99955	0.99955
r7	0	1.1738e-220	6.6059e-134	6.077e-69	9.9893e-26	0.00043152	0.00043152

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

CONTAINER NAME: mp_container_map Scalars

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	value
	-	---	-----
fl_ar1_persistence	1	2	0.99
fl_ar1_step	2	3	7.0179
fl_shk_std	3	4	0.99
it_std_bound	4	5	3

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

CONTAINER NAME: mp_container_map ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	ndim	numel	rowN	colN	sum	mean
	-	---	----	-----	---	---	-----	-----
ar_disc_ar1	1	1	2	7	7	1	3.4694e-18	4.9564e-19
mt_disc_ar1_trans	2	6	2	49	7	7	7	0.14286

xxx TABLE:ar_disc_ar1 xxxxxxxxxxxxxxxxxxxx
c1

r1 -0.030002
r2 -0.020001
r3 -0.010001
r4 0
r5 0.010001
r6 0.020001
r7 0.030002

xxx TABLE:mt_disc_ar1_trans xxxxxxxxxxxxxxxxxxxx
c1 c2 c3 c4 c5 c6 c7
----- ----- ----- ----- ----- ----- -----
r1 0.0067533 0.064018 0.2484 0.38278 0.23505 0.057298 0.0057011
r2 0.0065668 0.06286 0.24618 0.38287 0.23728 0.05838 0.0058656
r3 0.0063849 0.061717 0.24396 0.38292 0.2395 0.059478 0.0060344
r4 0.0062075 0.06059 0.24173 0.38294 0.24173 0.06059 0.0062075
r5 0.0060344 0.059478 0.2395 0.38292 0.24396 0.061717 0.0063849
r6 0.0058656 0.05838 0.23728 0.38287 0.24618 0.06286 0.0065668
r7 0.0057011 0.057298 0.23505 0.38278 0.2484 0.064018 0.0067533

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_container_map Scalars
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

	i	idx	value
	-	---	-----
fl_ar1_persistence	1	2	0.01
fl_ar1_step	2	3	0.010001
fl_shk_std	3	4	0.01
it_std_bound	4	5	3

Appendix A

Index and Code Links

A.1 Savings Dynamic Programming links

1. Looped Grid Infinite Horizon Dynamic Savings Problem: [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Infinite horizon constrained dynamic savings problem with persistent shock.
 - The state-space and choice-space share the same asset grid.
 - Looped algorithm, slow but easy to modify, useful for developing new models.
 - **MEconTools:** `ff_vfi_az_loop()`
2. Vectorized Grid Infinite Horizon Dynamic Savings Problem: [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Vectorized version of `ff_vfi_az_loop()`, fast and sufficiently approximate value(a,z), but choices not precise.
 - Broadcast and vectorized evaluation and maximization.
 - Solve u(c) once, and retrieve with cell arrays.
 - **MEconTools:** `ff_vfi_az_vec()`
3. Looped Exact FOC Infinite Horizon Dynamic Savings Problem: [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Infinite horizon constrained dynamic savings problem with persistent shock.
 - The state-space is on a grid, the choice space are continuous percentages of cash-on-hand.
 - Looped exact savings-percentage algorithm, slow but high precision at low grid size.
 - Solves for EV(ap,z) given shock state and for a savings choice. Bisection based on FOC with analytical du(c(ap))/dap and spline slopes dEV(ap,z)/dap.
 - **MEconTools:** `ff_vfi_az_bisec_loop()` + `ff_optim_bisec_savezrzone()`
4. Vectorized Exact FOC Infinite Horizon Dynamic Savings Problem: [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Vectorized version of `ff_vfi_az_bisec_loop()` exact savings-percentage algorithm, high precision and high speed.
 - **MEconTools:** `ff_vfi_az_bisec_vec()` + `ff_optim_bisec_savezrzone()`
5. Looped Exact Value Infinite Horizon Dynamic Savings Problem: [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Looped infinite horizon constrained dynamic savings problem with persistent shock.
 - The state-space is on a grid, the choice space are continuous percentages of cash-on-hand.
 - Evaluate value at choice grid iteratively by zooming-in to construct finer savings percentages.
 - **MEconTools:** `ff_vfi_az_mzoom_loop()` + `ff_optim_mzoom_savezrzone()`
6. Vectorized Exact Value Infinite Horizon Dynamic Savings Problem: [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Vectorized version of `ff_vfi_az_mzoom_loop()` exact savings-percentage algorithm.
 - **MEconTools:** `ff_vfi_az_mzoom_vec()` + `ff_optim_mzoom_savezrzone()`

A.2 Stationary Distribution links

1. Looped Grid Stationary Distribution Dynamic Savings Problem: [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Stationary distribution for infinite horizon constrained dynamic savings problem with persistent shock.
 - The state-space and choice-space share the same asset grid.
 - Looped algorithm.
 - **MEconTools:** `ff_ds_az_loop()`

2. Looped Exact Stationary Distribution Dynamic Savings Problem: [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Stationary distribution for infinite horizon constrained dynamic savings problem with persistent shock.
 - The state-space is on a grid, the choice space are continuous percentages of cash-on-hand.
 - Looped algorithm.
 - MEconTools: [ff_ds_az_cts_loop\(\)](#)

A.3 Summarize Policy and Value links

1. Summarize ND Array Policy and Value Functions: [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Given an NDarray matrix with N1, N2, ..., ND dimensions. Generate average and standard deviation for the 3rd dimension, grouping by the other dimensions.
 - For example, show the 5th dimension as the column groups, and the other variables generate combinations shown as rows.
 - The resulting summary statistics table contains mean and standard deviation among other statistics over the policy or value contained in the ND array.
 - MEconTools: [ff_summ_nd_array\(\)](#)

A.4 Distributional Analysis links

1. Gateway Joint Probability Mass Statistics: [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Given model policy functions and stationary distribution, compute distributional statistics.
 - Given discrete probability mass function $f(s)$, and information $y(s)$, $x(s)$, $z(s)$ at each element of the state-space, compute statistics for each variable, y , x , z , which are all discrete random variables.
 - Compute correlation and covariance between input discrete random variables.
 - MEconTools: [ff_simu_stats\(\)](#)
2. Discrete Random Variable Distributional Statistics: [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Model simulation generates discrete random variables, calculate mean, standard deviation, min, max, percentiles, and proportion of outcomes held by x percentiles, etc.
 - MEconTools: [ff_disc_rand_var_stats\(\)](#)
3. Generate Discrete Random Variable: [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Given mass at state space points, and y , c , a , z and other outcomes or other information at each corresponding state space points, generate discrete random variable, with unique sorted values, and mass for each unique sorted values.
 - Generate additional joint distributions: if initial distribution is over $f(a,z)$, generate joint distribution of $f(y,a)$ or $f(y,z)$.
 - MEconTools: [ff_disc_rand_var_mass2outcomes\(\)](#)
4. Discrete Random Variable Correlation and Covariance: [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Given probability mass function $f(s)$, $X(s)$, and $Y(s)$, compute the covariance and correlation between X and Y.
 - MEconTools: [ff_disc_rand_var_mass2covcor\(\)](#)

A.5 Optimizers links

1. Bisection Exact Optimal Savings Share Multiple States: [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Given a First Order Condition function handle that takes the fraction of resources (cash-on-hand) saved as the input, solve for the optimal savings fraction via bisection. Solve this concurrently for many elements of the state-space. The function handle contains the FOC with parameters and state-space elements embeded.
 - MEconTools: [ff_optim_bisec_savezone\(\)](#)
2. Multisection Exact Optimal Savings Share Multiple States: [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Given a First Order Condition function handle that takes the fraction of resources (cash-on-hand) saved as the input, solve for the optimal savings fraction via multisection where there are multiple evaluations per iteration of the FOC. Solve this concurrently for many elements of the state-space. The function handle contains the FOC with parameters and state-space elements embeded.

- **MEconTools:** [*ff_optim_mlsec_savezrzone\(\)*](#)
3. Vectorized Zooming Exact Optimal Savings Share Multiple States: [mlx](#) | [m](#) | [pdf](#) | [html](#)
- Given a Utility (not FOC) function handle that takes the fraction of resources (cash-on-hand) saved as the input, solve for the optimal savings fraction via iterative zooming where there are multiple evaluations per iteration of the utility function. Solve this concurrently for many elements of the state-space. The function handle contains the utility function with parameters and state-space elements embeded.
 - **MEconTools:** [*ff_optim_mzoom_savezrzone\(\)*](#)

A.6 Graphs links

1. Multiple Line Graph Function: [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Policy and Value Function graphs, x-axis one state, color another state, y-axis are value and policies.
 - Distributional graphs, x-axis one state, y-axis and color another state, size show distributional mass.
 - **MEconTools:** [*ff_graph_grid\(\)*](#)

A.7 Support Tools links

1. Organizes and Prints Container Map Key and Values: [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Summarizes the contents of a map container by data types. Includes, scalar, array, matrix, string, functions, tensors (3-tuples), tesseracts (4-tuples).
 - **MEconTools:** [*ff_container_map_display\(\)*](#)

A.8 Data Structures links

1. Log and Power Spaced Asset and Choice Grids: [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Generate linear, log-space, power-space, or threshold-cut asset or choice grids.
 - **MEconTools:** [*ff_saveborr_grid\(\)*](#)

A.9 Common Functions links

1. Discretize AR1 Normal Shock Tauchen (1986): [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Mean zero AR(1) shock discretize following Tauchen (1986).
 - **MEconTools:** [*ffy_tauchen\(\)*](#)
2. Discretize AR1 Normal Shock Rouwenhorst (1995): [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Mean zero AR(1) shock discretize following Rouwenhorst (1995).
 - **MEconTools:** [*ffy_rouwenhorst\(\)*](#)

A.10 System links

1. Search and Find File Names: [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Search and find file names.
 - **MEconTools:** [*ff_find_files\(\)*](#)
2. Execute and Export Livescript Files: [mlx](#) | [m](#) | [pdf](#) | [html](#)
 - Find livescript (mlx) files, execute MLX files, and export MLX files to HTML in a different folder.
 - **MEconTools:** [*ff_ml2htmlpdf_runandexport\(\)*](#)

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