FF_VFI_AZ_BISEC_LOOP Dynamic Savings Problem Loop Continuous Choice

back to Fan's Intro Math for Econ, Matlab Examples, or Dynamic Asset Repositories

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 (face some borrowing constraint), 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 Four Code:

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

- Common Choice and States Grid ***Loop***: **ff_vfi_az_loop**, slow should use for testing new models
- Common Choice and States Grid ***Vectorized***: **ff_vfi_az_vec**, fast good for many purposes
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand ***Loop***: **ff_vfi_az_bisec_loop**, high precision even with small grid
- States Grid + Continuous Exact Savings as Share of Cash-on-Hand ***Vectorized***: **ff_vfi_az_bisec_vec**, precision and speed

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 31.520504 seconds.
----------------------------------------
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefvari	min	max
ap	1	1	2	700	100	7	16866	24.094	14.071	0.58399	0	50.252

```
xxx TABLE:ap xxxxxxxxxxxxxxxxx
```

	c1	c2	c3	c4	c5	c6	c7
r1	0	0	0	0	0.13188	0.66203	1.9859
r2	0.25914	0.26426	0.29511	0.39221	0.57697	1.1208	2.4569
r3	0.65371	0.66543	0.70966	0.82502	1.029	1.582	2.9298
r4	1.0748	1.0921	1.1447	1.2698	1.5151	2.0481	3.4046

r5	1.5152	1.5319	1.5903	1.721	2.0011	2.5252	3.8802
r96	45.561	45.615	45.712	45.887	46.192	46.835	48.252
r97	46.049	46.104	46.201	46.377	46.681	47.325	48.743
r98	46.54	46.593	46.69	46.866	47.171	47.815	49.235
r99	47.029	47.082	47.179	47.356	47.661	48.304	49.734
r100	47.518	47.572	47.67	47.845	48.15	48.793	50.252

Test FF_VFI_AZ_BISEC_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') = {};
```

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 9.142315 seconds.
```

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_vfi_az_bisec_loop(mp_params, mp_support);
```

```
Elapsed time is 26.910198 seconds.
```

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_vfi_az_bisec_loop(mp_params, mp_support);
```

```
Elapsed time is 74.127079 seconds.
```

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') = false;
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
```

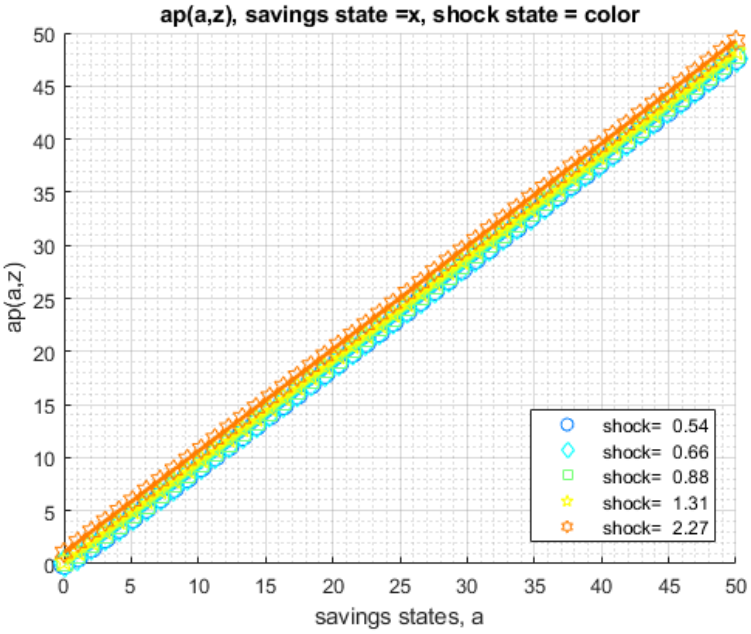
Run the function and show policy function for savings choice. For ls_ffcmd, ls_ffsna, ls_ffgrh, can include these: 'v', 'ap', 'c', 'y', 'coh', 'savefraccoh'. These are value, aprime savings choice, consumption, income, cash on hand, and savings fraction as cash-on-hand.

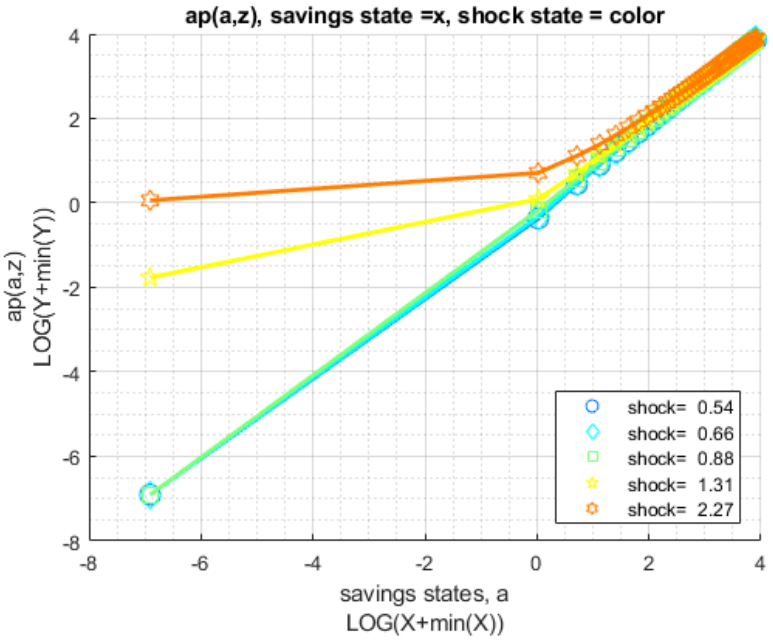
```
mp_support = containers.Map('KeyType','char', 'ValueType','any');
mp_support('bl_print_params') = false;
mp_support('bl_print_iterinfo') = false;
% ls_ffcmd: summary print which outcomes
mp_support('ls_ffcmd') = {};
% ls_ffsna: detail print which outcomes
mp_support('ls_ffsna') = {'ap'};
% ls_ffgrh: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

```
Elapsed time is 9.221215 seconds.
xxx  ff_vfi_az_vec, outcome=ap  xxxxxxxxxxxxxxxxxxxxxxxxxxx
```

group	a	mean_z_0_54195	mean_z_0_66401	mean_z_0_88162	mean_z_1_3095	mean_z_2_2745
1	0	0	0	0	0.17037	1.0635
2	1.0204	0.69295	0.72405	0.84423	1.099	2.0409
3	2.0408	1.5665	1.6143	1.7589	2.0408	3.0571
4	3.0612	2.4757	2.534	2.6903	3.0612	4.0135
5	4.0816	3.4036	3.4686	3.6319	4.0274	4.9775
6	5.102	4.3431	4.4131	4.5822	4.9848	5.9445
7	6.1224	5.2908	5.3648	5.5384	5.9466	6.9138
8	7.1429	6.2445	6.3216	6.4989	6.9116	7.8851
9	8.1633	7.2029	7.2827	7.463	7.8793	8.8584
10	9.1837	8.1651	8.2469	8.4301	8.8495	9.8329
11	10.204	9.1837	9.2139	9.3992	9.8212	10.809
12	11.224	10.175	10.204	10.37	10.795	11.785
13	12.245	11.141	11.225	11.343	11.769	12.763
14	13.265	12.109	12.198	12.316	12.745	13.742
15	14.286	13.079	13.169	13.291	13.721	14.72
16	15.306	14.051	14.142	14.286	14.699	15.7
17	16.327	15.026	15.117	15.306	15.677	16.68
18	17.347	16.001	16.093	16.289	16.655	17.66
19	18.367	16.978	17.069	17.265	17.634	18.641
20	19.388	17.955	18.048	18.243	18.614	19.623
21	20.408	18.934	19.026	19.223	19.595	20.606
22	21.429	19.913	20.006	20.203	20.577	21.589
23	22.449	20.894	20.986	21.184	21.559	22.573
24	23.469	21.875	21.968	22.166	22.542	23.557
25	24.49	22.856	22.95	23.148	23.525	24.542
26	25.51	23.838	23.932	24.131	24.509	25.526
27	26.531	24.821	24.915	25.114	25.51	26.531
28	27.551	25.804	25.899	26.098	26.531	27.551
29	28.571	26.788	26.883	27.082	27.524	28.538
30	29.592	27.772	27.867	28.067	28.507	29.524
31	30.612	28.757	28.852	29.052	29.492	30.509
32	31.633	29.742	29.837	30.037	30.477	31.496
33	32.653	30.727	30.822	31.023	31.463	32.483
34	33.673	31.712	31.808	32.009	32.449	33.47
35	34.694	32.698	32.795	32.995	33.435	34.457
36	35.714	33.685	33.781	33.982	34.422	35.445
37	36.735	34.694	34.768	34.969	35.41	36.432
38	37.755	35.714	35.755	35.955	36.397	37.421
39	38.776	36.703	36.741	36.942	37.385	38.409
40	39.796	37.689	37.755	37.93	38.372	39.397

41	40.816	38.676	38.774	38.918	39.361	40.387
42	41.837	39.663	39.761	39.906	40.349	41.375
43	42.857	40.65	40.749	40.894	41.337	42.365
44	43.878	41.637	41.736	41.881	42.326	43.353
45	44.898	42.624	42.724	42.87	43.314	44.342
46	45.918	43.612	43.711	43.877	44.303	45.331
47	46.939	44.6	44.7	44.898	45.293	46.321
48	47.959	45.589	45.688	45.893	46.281	47.311
49	48.98	46.577	46.676	46.881	47.27	48.3
50	50	47.566	47.664	47.87	48.259	49.289





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 35.765637 seconds.
----------------------------------------
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefvari	min	
ap	1	1	2	900	100	9	21835	24.261	14.095	0.58096	0	
savefraccoh	2	2	2	900	100	9	754.27	0.83808	0.1259	0.15023	0	0.

xxx TABLE:ap xxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6	c7	c8	c9
r1	0	0	0	0	0	0.082559	0.50504	1.2988	3.1416
r2	0.26067	0.25936	0.26888	0.30308	0.39296	0.52492	0.96211	1.7672	3.6183
r3	0.65383	0.65589	0.67297	0.71974	0.82473	1.0101	1.4185	2.2377	4.0955
r4	1.0734	1.0789	1.1015	1.1556	1.2679	1.4909	1.8821	2.7095	4.5736
r5	1.5151	1.5159	1.5427	1.6019	1.72	1.9489	2.349	3.1825	5.0521
r96	45.547	45.58	45.636	45.73	45.888	46.134	46.603	47.52	49.54
r97	46.036	46.069	46.126	46.22	46.377	46.622	47.092	48.009	50.057
r98	46.525	46.559	46.615	46.71	46.867	47.112	47.583	48.501	50.575
r99	47.014	47.049	47.104	47.198	47.357	47.601	48.072	48.992	51.092
r100	47.503	47.537	47.593	47.687	47.845	48.091	48.561	49.495	51.61

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5	c6	c7	c8	c9
r1	0	0	0	0	0	0.056268	0.24587	0.41301	0.58272
r2	0.23098	0.217	0.20843	0.21203	0.23925	0.26445	0.3741	0.48253	0.61235
r3	0.39717	0.38292	0.37227	0.36965	0.38179	0.40361	0.45915	0.53532	0.63728
r4	0.49605	0.48369	0.47368	0.46883	0.47347	0.49364	0.52177	0.57677	0.65861
r5	0.56502	0.55159	0.54262	0.53709	0.53825	0.55086	0.56947	0.61021	0.67704
r96	0.91477	0.91422	0.91361	0.91294	0.91221	0.9109	0.90961	0.90818	0.90781
r97	0.91508	0.91453	0.91395	0.91328	0.91254	0.91123	0.90998	0.90855	0.90867
r98	0.91538	0.91486	0.91425	0.91361	0.91288	0.91157	0.91035	0.90894	0.90952
r99	0.91569	0.91517	0.91456	0.91392	0.91322	0.9119	0.91068	0.90934	0.91035
r100	0.91596	0.91544	0.91486	0.91422	0.91352	0.91224	0.91102	0.90992	0.91117

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') = 50;
mp_params('it_z_n') = 5;
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 2.672239 seconds.
----------------------------------------
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
                  i    idx    ndim    numel    rowN    colN     sum      mean       std      coefvari    min
                  _    ___    ____    _____    ____    ____    ______    _______    _______    ________    ___

    savefraccoh   1     1      2       250      50      5      119.77    0.47907    0.28808    0.60133      0

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx
            c1         c2         c3         c4         c5
        _______    _______    _______    _______    _______

    r1          0          0          0          0    0.10641
    r2          0          0          0          0    0.10641
    r3          0          0          0          0    0.10629
    r4          0          0          0          0    0.10601
    r5          0          0          0          0    0.10793
    r46   0.79096    0.78788    0.78242    0.77293    0.76768
    r47   0.79554    0.79261    0.78749    0.77754    0.77168
    r48   0.79991    0.79716    0.79228    0.78291     0.7754
    r49   0.80406    0.80146    0.79688      0.788    0.77891
    r50   0.80699    0.80396     0.8003    0.79283    0.78218
```

```
% 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 11.445094 seconds.
----------------------------------------
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
                  i    idx    ndim    numel    rowN    colN     sum      mean       std      coefvari    min
                  _    ___    ____    _____    ____    ____    ______    _______    _______    ________    ___

    savefraccoh   1     1      2       250      50      5      162.74    0.65097    0.29744    0.45693      0

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx
            c1         c2          c3         c4         c5
        _______    _______    ________    _______    _______

    r1          0          0    0.029138    0.21236    0.45384
    r2          0          0    0.029535    0.21258     0.4539
    r3          0          0     0.03219    0.21401    0.45448
    r4          0          0    0.039301    0.21795    0.45607
    r5          0          0    0.045923    0.22542    0.45909
    r46    0.9221    0.92124     0.92029    0.91929    0.91587
    r47   0.92408    0.92329     0.92237    0.92142    0.91816
    r48   0.92591    0.92518     0.92432    0.92344    0.92057
    r49   0.92762    0.92692     0.92612    0.92536    0.92347
    r50   0.92924     0.9286     0.92792    0.92737    0.92783
```

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') = 5;
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:

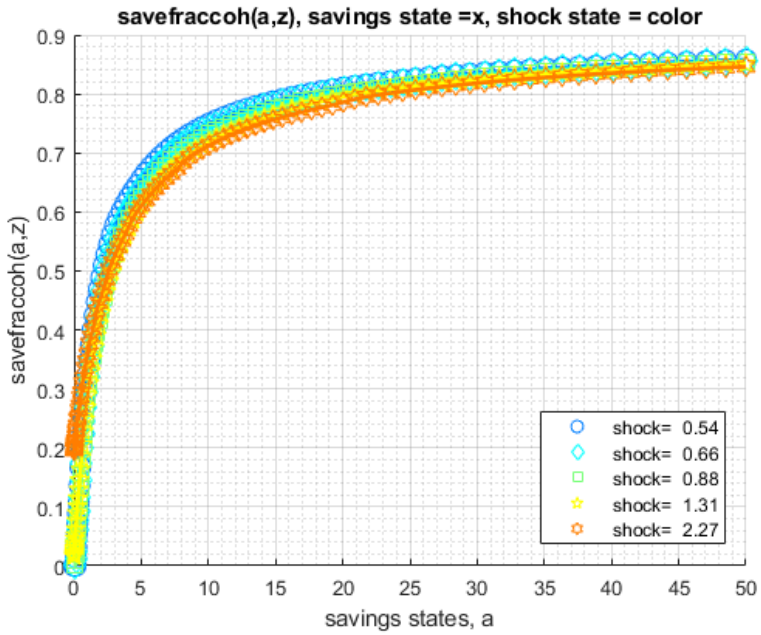
```
% Lower Risk Aversion
mp_params('fl_crra') = 0.5;
ff_vfi_az_bisec_loop(mp_params, mp_support);
```

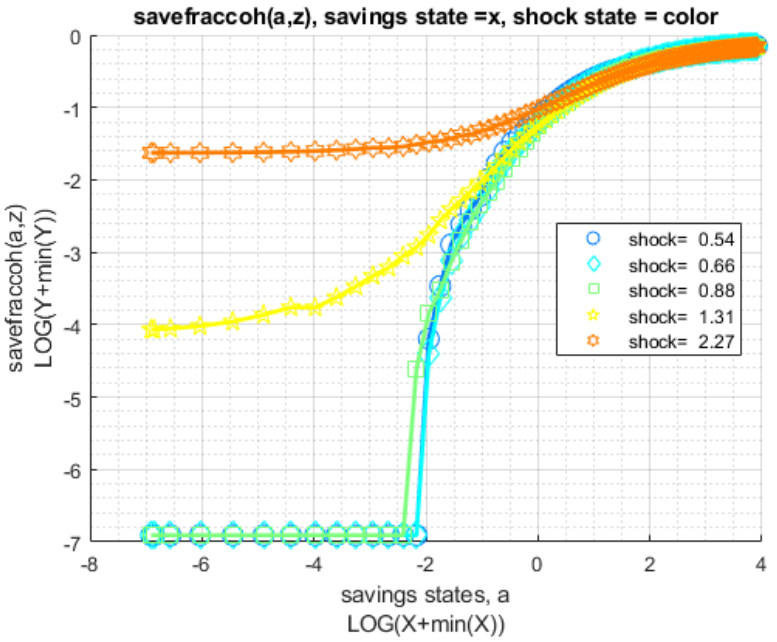
```
Elapsed time is 20.016228 seconds.
----------------------------------------
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefvari	min	
savefraccoh	1	1	2	500	100	5	270.24	0.54048	0.30018	0.5554	0	0

```
xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxxx
```

	c1	c2	c3	c4	c5
r1	0	0	0	0.016108	0.19552
r2	0	0	0	0.016138	0.19555
r3	0	0	0	0.016352	0.19564
r4	0	0	0	0.016962	0.19591
r5	0	0	0	0.018091	0.19646
r96	0.85334	0.85127	0.84879	0.84602	0.84037
r97	0.85456	0.85255	0.85017	0.84748	0.8419
r98	0.85578	0.85383	0.85151	0.84889	0.84339
r99	0.85694	0.85502	0.85279	0.85023	0.84483
r100	0.85804	0.85621	0.85404	0.85154	0.84623





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

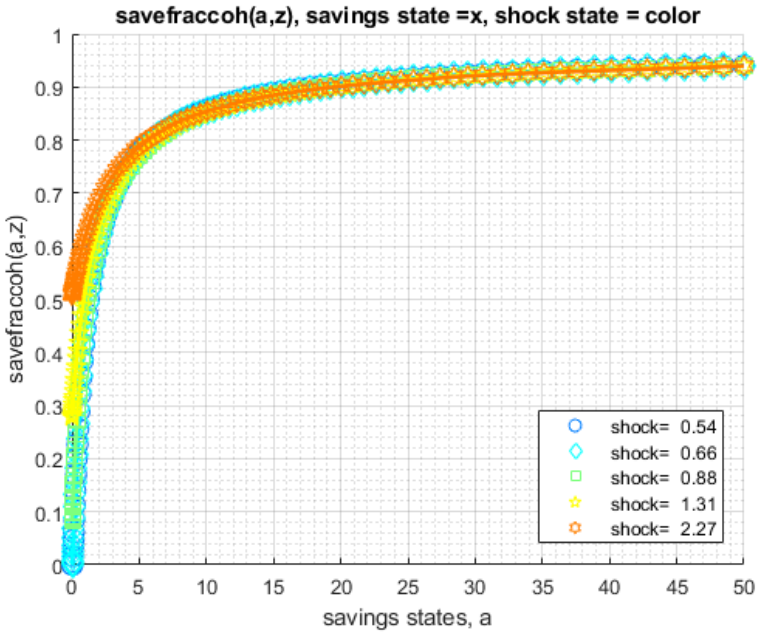
```
% Higher Risk Aversion
mp_params('fl_crra') = 5;
ff_vfi_az_bisec_loop(mp_params, mp_support);
```

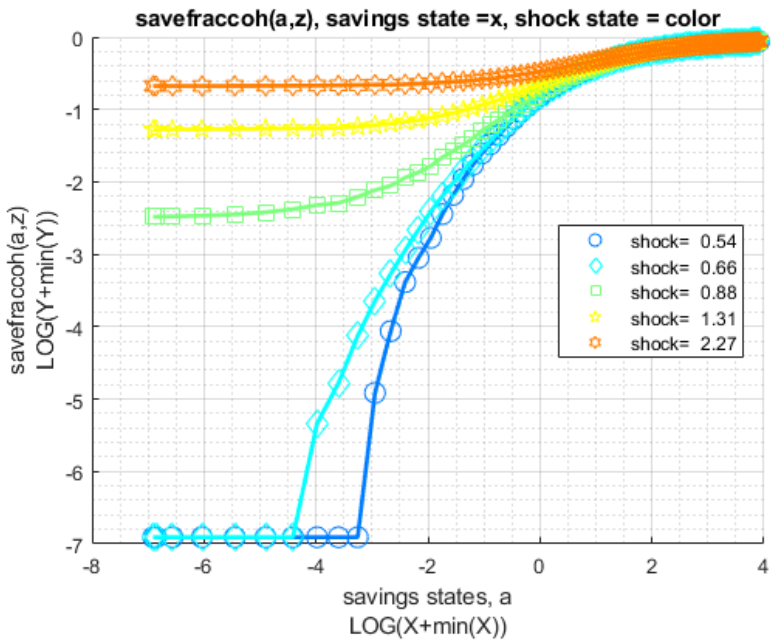
```
Elapsed time is 19.070686 seconds.
----------------------------------------
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
                  i    idx    ndim    numel    rowN    colN     sum      mean       std      coefvari    min
                  _    ___    ____    _____    ____    ____    ______    _______    _______    ________    ___

    savefraccoh   1      1       2      500      100      5      337.39    0.67477    0.28798    0.42678      0      0
```

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5
r1	0	0	0.082635	0.2781	0.5078
r2	0	0	0.082665	0.27813	0.5078
r3	0	0	0.08297	0.27828	0.50786
r4	0	0	0.083794	0.27871	0.50801
r5	0	0	0.085381	0.27956	0.50835
r96	0.93751	0.93699	0.93641	0.93586	0.93482
r97	0.93839	0.9379	0.93732	0.9368	0.93586
r98	0.93925	0.93876	0.93824	0.93775	0.93702
r99	0.9401	0.93961	0.93909	0.93867	0.93839
r100	0.94089	0.94044	0.93998	0.93961	0.94013





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') = 100;
mp_params('it_z_n') = 5;
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_bisec_loop(mp_params, mp_support);
```

```
Elapsed time is 19.744605 seconds.
----------------------------------------
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefvari	min
savefraccoh	1	1	2	500	100	5	295.24	0.59048	0.32213	0.54554	0

```
xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxxx
```

	c1	c2	c3	c4	c5
r1	0	0	0	0.030451	0.12142
r2	0	0	0	0.030481	0.12145
r3	0	0	0	0.030725	0.12164
r4	0	0	0	0.031366	0.12209
r5	0	0	0	0.032648	0.12304
r96	0.90824	0.90775	0.90726	0.90675	0.90629
r97	0.90943	0.90894	0.90845	0.90797	0.90751
r98	0.91056	0.9101	0.90961	0.90916	0.9087
r99	0.91166	0.9112	0.91074	0.91029	0.90983
r100	0.9127	0.91227	0.91184	0.91138	0.91096

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_bisec_loop(mp_params, mp_support);
```

```
Elapsed time is 17.556461 seconds.
----------------------------------------
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
CONTAINER NAME: mp_ffcmd ND Array (Matrix etc)
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

	i	idx	ndim	numel	rowN	colN	sum	mean	std	coefvari	min	
savefraccoh	1	1	2	500	100	5	354.06	0.70811	0.27055	0.38207	0	0

xxx TABLE:savefraccoh xxxxxxxxxxxxxxxxx

	c1	c2	c3	c4	c5
r1	0	0	0.030725	0.36968	0.77064
r2	0	0	0.030725	0.36968	0.77064
r3	0	0	0.030695	0.36959	0.77064
r4	0	0	0.030634	0.36934	0.77061
r5	0	0	0.030542	0.36885	0.77043
r96	0.92429	0.92289	0.92091	0.91688	0.92026
r97	0.92496	0.92362	0.92173	0.91795	0.92231
r98	0.92564	0.92432	0.92252	0.91898	0.92429
r99	0.92628	0.92503	0.92332	0.91999	0.92625
r100	0.92689	0.9257	0.92408	0.92103	0.92811