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Import and select data & Graph Cumulative Returns to Assets

```
clear;clc;
cd 'Exercise Set 5'\;
%Read Portfolio Asset Classes
tblAssets =
 readtable('ExcerciseSet1_YuanzhanGao_AdityaKumar.xlsx','sheet','Returns');
```

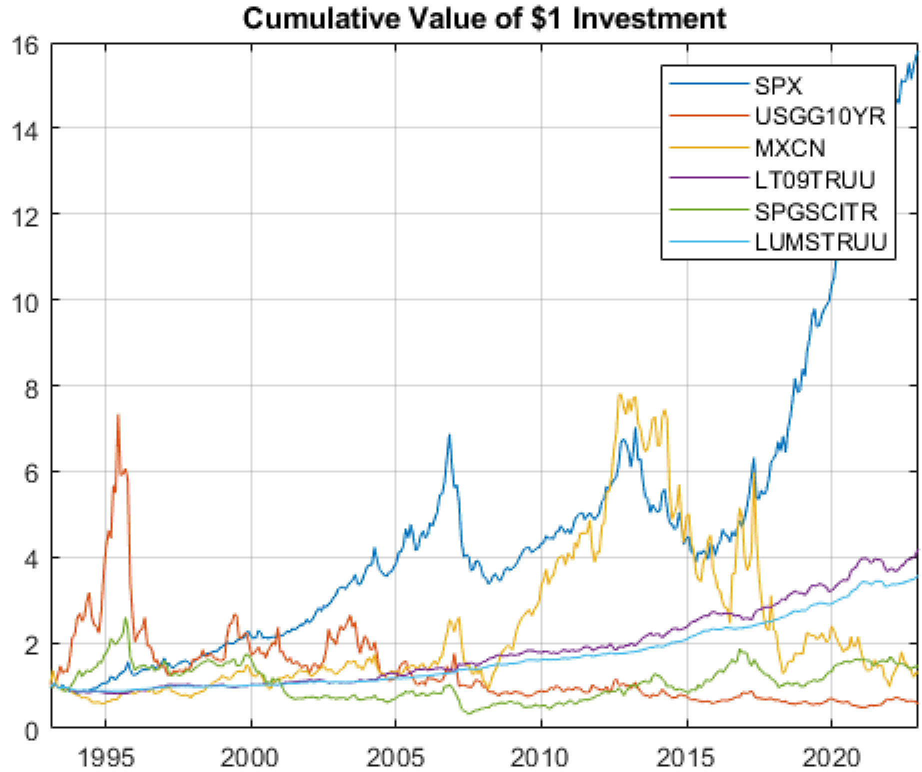
Warning: Column headers from the file were modified to make them valid MATLAB identifiers before creating variable names for the table. The original column headers are saved in the VariableDescriptions property.
Set 'VariableNamingRule' to 'preserve' to use the original column headers as table variable names.

Question 1

```
date = datetime(tblAssets.Date);
% remove NaN rows
date(1, :) = [];
date(361:365, :) = [];
% reverse order to get correct date column
date_ordered = flip(date, 1);
% six indexes:
%1) SPX: S&P 500 - US general stocks performance; best return
%2) USGG10YR: 10YR Treasury
% 9 YR Treasury and MBS are used to hedge the risk
M = [tblAssets.SPXIndex, tblAssets.USGG10YRIndex, tblAssets.MXCNIndex,
 tblAssets.LT09TRUUIndex, tblAssets.SPGSCITRIndex, tblAssets.LUMSTRUUIndex];
```

```
AssetNames = {'SPX', 'USGG10YR', 'MXCN', 'LT09TRUU', 'SPGSCITR', 'LUMSTRUU'};
% % Drop unwanted rows and calculate cumulative returns
M(362:366, :) = [];
% set first row equal 0, so 1+0 = 1
M(1, :) = 0;
cum_M = cumprod(1+M);
% remove the first row for unmatched dimensionality
cum_M(1, :) = [];
% plot cumulative return of 1 dollar
figure(1);
plot(date_ordered, cum_M); title('Cumulative Value of $1
 Investment');legend('SPX', 'USGG10YR', 'MXCN', 'LT09TRUU', 'SPGSCITR', 'LUMSTRUU');grid o

% Table for cumulative return and annualized monthly (mean) return
% Question 1 continue
total_month = size(cum_M, 1);
return_table = table([cum_M(360, 1);cum_M(360, 2);cum_M(360, 3);cum_M(360,
 4);cum_M(360, 5);cum_M(360, 6);], ...
    [cum_M(360, 1)^(12/total_month)-1;cum_M(360, 2)^(12/
total_month)-1;cum_M(360, 3)^(12/total_month)-1;cum_M(360, 4)^(12/
total_month)-1;cum_M(360, 5)^(12/total_month)-1;cum_M(360, 6)^(12/
total_month)-1;], ...
    'RowNames', AssetNames, ...
    'VariableNames',{'Cumulative Dollar Return($)','Annualized Mean
 Return(%)'});

disp(return_table);
```

	Cumulative Dollar Return($)	*Annualized Mean Return(%)*
SPX	*15.808*	*0.096384*
USGG10YR	*0.57954*	*-0.01802*
MXCN	*1.2983*	*0.00874*
LT09TRUU	*4.1879*	*0.048898*
SPGSCITR	*1.4607*	*0.01271*
LUMSTRUU	*3.5671*	*0.043303*



2.a. Set Portfolio Optimization Constraints & Options

```
% Construct the variance/Covariance matrix

%r remove first row of M (currently 0 which is added for 1$ cum return
%calculation)
if size(M, 1) == 361
    M(1, :) = [];
end

T = size(M, 1);
for t = 36:T
    V = cov(M(t-35:t,:));
    Vcov(:,:,t) = V; Vcond(t) = cond(V);
end

% calculate monthly mean return
mean_return = (prod(1+M).^(1/T)-1);

% Set up conditions for quadratic programming
nAssets = size(M, 2); r = 0.0055;      % number of assets and desired return
 (use monthly return here)
```

```
Aeq = ones(1,nAssets); beq = 1;              % equality Aeq*x = beq (all sum
 to 1)
Aineq = -mean_return; bineq = -r;            % inequality Aineq*x <= bineq
% why negative:
% since quadprog's 3rd and 4th parameter only sets up the constraint as
% A*x < b, to reach a return greater than designated r, the return needs
% to be greater than r in absolute value, or less than -r when the return
% and r are both positive.


lb = zeros(nAssets,1); ub = ones(nAssets,1); % bounds lb <= x <= ub (no
 shorting)
c = zeros(nAssets,1);                        % objective has no linear term;
 set it to zero
% Select Options for Quadprog
options = optimset('Algorithm','interior-point-convex');
options = optimset(options,'Display','off','TolFun',1e-10);
```

Optimize three base and three stress cases

```
dateStr = datestr(date);
n = strmatch('30-Jul-2010',dateStr,'exact');
% Base case:
Vbase = cov(M);  % Average through whole sample
wmvBase = quadprog(Vbase,c,[],[],Aeq,beq,[],[],[],options); % allow shorting
wBase = quadprog(Vbase,c,Aineq,bineq,Aeq,beq,lb,ub,[],options); % greater or
 equal than target return; does not allow shorting
wrpBase = riskBudgetingPortfolio(Vbase);

% Stress case
Vstress = Vcov(:,:,n);  % n = location for '30-Jul-2010'
wmvStress = quadprog(Vstress,c,[],[],Aeq,beq,[],[],[],options);
wStress = quadprog(Vstress,c,Aineq,bineq,Aeq,beq,lb,ub,[],options);
wrpStress = riskBudgetingPortfolio(Vstress);
```

2. Continue: Table Result

2.a. Portofolio Weights

```
PortWts = table(wmvBase,
 wmvStress,wBase,wStress,wrpBase,wrpStress,'RowNames',AssetNames);
disp("Portofolio Weights");
disp(PortWts);
disp("In the minimal variance portofolio for both the base and stress cases,
 we find that we are shorting several of the assets in our portfolio. This
 makes sense as a way to ensure minimum variance in returns. In the targeted
 return portfolio, both the base and stress case involve heavily investing in
 two assets (SPX & LT09TRUU), and not really investing in any other. This is
 to hit a higher targeted rate of return. However, the risk parity portfolio
 (for both cases) reduces overall riskiness by still focising on ivesting in
 those two assets, but with a much greater spread. This is in contrast to the
```

```
targeted rate of return portfolio, which exclusively invests in those two
assets.");
```

Portofolio Weights

	wmvBase	wmvStress	wBase	wStress	wrpBase	wrpStress
SPX	-0.0086748	0.014877	0.40787	0.40787	0.05299	0.034393
USGG10YR	0.1008	0.08139	2.6688e-08	5.1809e-09	0.10114	0.084764
MXCN	-0.0018284	-0.011656	3.6072e-12	1.4674e-11	0.026759	0.018398
LT09TRUU	0.29892	0.34193	0.59213	0.59213	0.43269	0.51567
SPGSCITR	-0.0037402	-0.013944	7.4297e-12	2.5217e-11	0.039523	0.022866
LUMSTRUU	0.61453	0.58741	1.8851e-08	7.4678e-09	0.3469	0.32391

In the minimal variance portofolio for both the base and stress cases, we find that we are shorting several of the assets in our portfolio. This makes sense as a way to ensure minimum variance in returns. In the targeted return portfolio, both the base and stress case involve heavily investing in two assets (SPX & LT09TRUU), and not really investing in any other. This is to hit a higher targeted rate of return. However, the risk parity portfolio (for both cases) reduces overall riskiness by still focising on ivesting in those two assets, but with a much greater spread. This is in contrast to the targeted rate of return portfolio, which exclusively invests in those two assets.

2.b. Portofolio month Returns

```
% Expected Return for each of the portofolio
% we use the mean return of the portofolio
```

MONTHLY RETURN!! (SINCE mean_return is the average monthlized return over the entire 30 years span)

```
Rmv_base =  mean_return * wmvBase;
Rmv_stress = mean_return* wmvStress;
R_base = mean_return * wBase;
R_stress = mean_return* wStress;
Rrp_base = mean_return * wrpBase;
Rrp_stress = mean_return * wrpStress;
PortRet = table([Rmv_base; R_base; Rrp_base],
 [Rmv_stress;R_stress;Rrp_stress],'RowNames',
{'mv','targRet','riskparity'},'VariableNames',{'Base','Stress'});
```

```
disp(PortRet);
disp("The returns are as expected for each portfolio. The minimum variance
 portfolio has the lowest return because it sacrifices returns for less risk.
 On the other hand, the target rate of return portfolio hits the target rate
 exactly, while the risk parity portfolio is somehwere in the middle, due to
 its distribution of risk.  ");
```

	Base	Stress
mv	*0.0031416*	*0.0034099*
targRet	*0.0055*	*0.0055*
riskparity	*0.0032682*	*0.0033757*

The returns are as expected for each portfolio. The minimum variance portfolio has the lowest return because it sacrifices returns for less risk. On the other hand, the target rate of return portfolio hits the target rate exactly, while the risk parity portfolio is somehwere in the middle, due to its distribution of risk.

2.c. portofolio risks

```
riskBase = round(sqrt(wBase'*(12*Vbase)*wBase),3);
riskStress = round(sqrt(wStress'*(12*Vstress)*wStress),3);

riskParityBase = round(sqrt(wrpBase'*(12*Vbase)*wrpBase),3);
riskParityStress = round(sqrt(wrpStress'*(12*Vstress)*wrpStress),3);

riskScenarios = table(riskBase,riskStress,riskParityBase,riskParityStress, ...
    'VariableNames',
{'MaxSharpeBase','MaxSharpeStress','RiskParityBase','RiskParityStress'});
disp(riskScenarios);
disp("The risks also match up with what we know about the allocations for
 each portfolio. The risk parity portfolio has lower risk in both cases, as
 the risk parity method distributes risk. Additionally, risk is lower for the
 stress case than the base case for both portfolios. ")
```

MaxSharpeBase	*MaxSharpeStress*	*RiskParityBase*	*RiskParityStress*
0.068	*0.046*	*0.029*	*0.016*

The risks also match up with what we know about the allocations for each portfolio. The risk parity portfolio has lower risk in both cases, as the risk parity method distributes risk. Additionally, risk is lower for the stress case than the base case for both portfolios.

2.d. MCR

```
MCR = table(round(12*Vbase*wBase/riskBase,3), round(12*Vstress*wStress/
riskStress,3), round(12*Vbase*wrpBase/riskParityBase,3),
 round(12*Vstress*wrpStress/riskParityStress,3),'VariableNames',
 {'MCRBase', 'MCRStress', 'MCRRPBase', 'MCRRPStress'},'RowNames', AssetNames);
```

```
disp(MCR);
disp("In both the stress cases, the MCR is more evenly distributed among
 every asset for the risk parity portfolio. This makes sense in the context
 of the weights of either portfolio. The targeted rate of return portfolio
 invested more heavily in a few assets while the risk parity portfolio spread
 out ivestment. Does, the MCR was more evenly distributed for the risk parity
 portfolio but concentrated in a certain few assets for the targeted rate of
 return portfolio.")
```

	MCRBase	*MCRStress*	*MCRRPBase*	*MCRRPStress*
SPX	*0.125*	*0.101*	*0.09*	*0.076*
USGG10YR	*-0.108*	*-0.039*	*0.047*	*0.031*
MXCN	*0.124*	*0.136*	*0.179*	*0.141*
LT09TRUU	*0.028*	*0.008*	*0.011*	*0.005*
SPGSCITR	*0.042*	*0.111*	*0.121*	*0.114*
LUMSTRUU	*0.017*	*0.008*	*0.014*	*0.008*

In both the stress cases, the MCR is more evenly distributed among every asset for the risk parity portfolio. This makes sense in the context of the weights of either portfolio. The targeted rate of return portfolio invested more heavily in a few assets while the risk parity portfolio spread out ivestment. Does, the MCR was more evenly distributed for the risk parity portfolio but concentrated in a certain few assets for the targeted rate of return portfolio.

2.e. Risk Attribution/Budget

```
riskBudget_Base = round((12*Vbase*wBase/riskBase).*wBase,3);
riskBudget_Stress = round((12*Vstress*wStress/riskStress).*wStress,3);
riskBudget_rp_Base = round((12*Vbase*wrpBase/riskParityBase).*wrpBase,3);
riskBudget_rp_Stress = round((12*Vstress*wrpStress/
riskParityStress).*wrpStress,3);
RiskBudget = table(riskBudget_Base, riskBudget_Stress,
 riskBudget_rp_Base, riskBudget_rp_Stress, 'VariableNames',
 {'RiskBudgetBase', 'RiskBudgetStress', 'RiskBudgetRPBase', 'RiskBudgetRPStress'}, 'RowNam
disp(RiskBudget);
disp("Unsurprisingly, the risk budget is reflective of the broader trends
 already identified. The risk parity portfolio has an equally distributed
 risk budget while the targeted rate of return portfolio has a risk budget
 concentrated on certain assets designed to offer a higher potential return.")
```

	RiskBudgetBase	*RiskBudgetStress*	*RiskBudgetRPBase*	*RiskBudgetRPStress*
SPX	*0.051*	*0.041*	*0.005*	*0.003*
USGG10YR	*0*	*0*	*0.005*	*0.003*
MXCN	*0*	*0*	*0.005*	*0.003*

```
    LT09TRUU         0.016              0.005               0.005
  0.003
    SPGSCITR             0                  0               0.005
  0.003
    LUMSTRUU             0                  0               0.005
  0.003
```

Unsurprisingly, the risk budget is reflective of the broader trends already identified. The risk parity portfolio has an equally distributed risk budget while the targeted rate of return portfolio has a risk budget concentrated on certain assets designed to offer a higher potential return.

3. Estimate VaR at the 1-percent level for each of the six portfolios. Tell me exactly what these mean for the three portfolios under both the Base and Stress cases.

```
VaR_01 = ((1+[R_base, R_stress, Rrp_base, Rrp_stress]).^12 -1) +
 norminv([0.005, 0.995])'*[table2array(riskScenarios)];
Var01_table = array2table(VaR_01, 'RowNames',
{'Upper Bound', 'Lower Bound'}, 'VariableNames',
 {'R_Base', 'R_Stress', 'R_rp_Base', 'R_rp_Stress'});
disp("We are 99% confident that the annualized expected return for each
 portofolio is as follows:");
disp(Var01_table);
disp("For the target return portofolio in base case, we are 99% confident that
 the annualized return falls between -10.7% and 24.3%.");
disp("For the target return portofolio in stress case, we are 99% confident
 that the annualized return falls between -5.04% and 18.7%.");
disp("For the risk parity return portofolio in base case, we are 99% confident
 that the annualized return falls between -3.48% and 11.5%.");
disp("For the risk parity return portofolio in stress case, we are 99%
 confident that the annualized return falls between 0.0057% and 8.25%.");
```

We are 99% confident that the annualized expected return for each portofolio is as follows:

	R_Base	R_Stress	R_rp_Base	R_rp_Stress
Upper Bound	-0.10712	-0.050455	-0.034767	5.5749e-05
Lower Bound	0.24319	0.18652	0.11463	0.082482

For the target return portofolio in base case, we are 99% confident that the annualized return falls between -10.7% and 24.3%.
For the target return portofolio in stress case, we are 99% confident that the annualized return falls between -5.04% and 18.7%.
For the risk parity return portofolio in base case, we are 99% confident that the annualized return falls between -3.48% and 11.5%.
For the risk parity return portofolio in stress case, we are 99% confident that the annualized return falls between 0.0057% and 8.25%.

Question 4

```
% 4.a
%Base case target Return
R_Base_total = M*wBase;
% Read in BlackRock factor
Factors =
 readtable('ExcerciseSet1_YuanzhanGao_AdityaKumar.xlsx','sheet','BLK_AQR');
dateFactor = datetime(Factors.DATE);
BR_factors = [Factors.RealRates, Factors.Inflation, Factors.Credit,
 Factors.Economic, Factors.EmergingMarkets, Factors.Liquidity];
[T,k]= size(BR_factors);
```

Trim the BR_factors matrix to date we are interested in StartDate is Jan-93

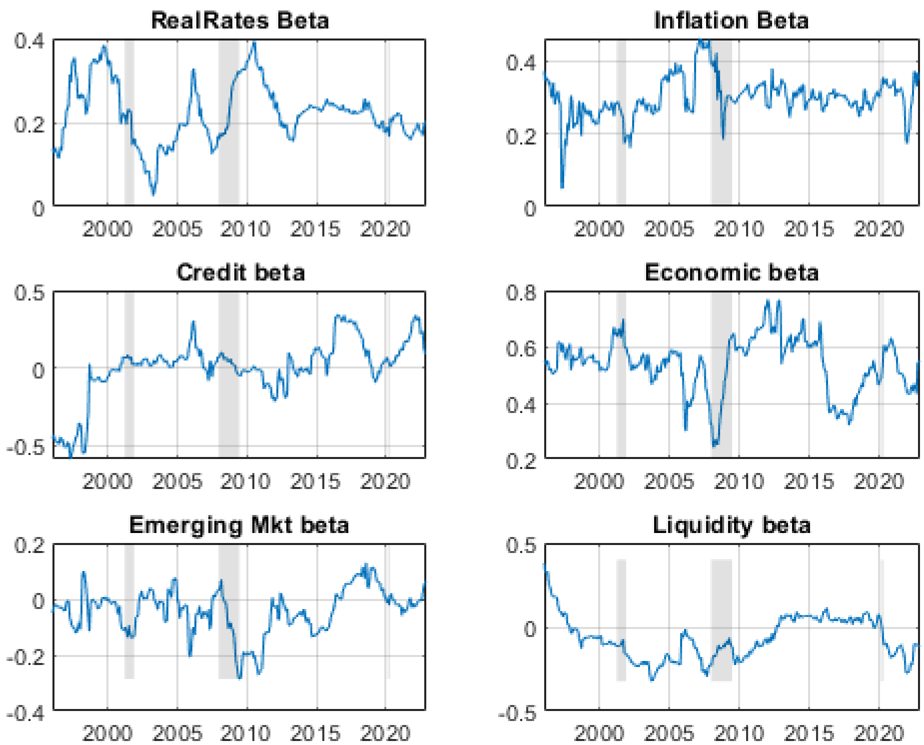
```
start_date = strmatch('31-Jan-1993', datestr(dateFactor), 'exact');
% EndDate is Dec-22, which the BR_factors do not have in the dataset; we
% will just use Nov-22 and drop the first row of target-return which is for
% Dec-2022
BR_factors_trimmed = BR_factors(start_date:end, :);

% Reverse the target return matrix R_Base_total to match the date sequence
% now Dec-2022 is at the bottom, correponding to the dateFactor
R_Base_t_reversed = flip(R_Base_total, 1);

% Find Betas for BlackRock factors with a 36-months trailing
b = zeros(size(BR_factors_trimmed,1), 7); % create an empty matrix to store
 betas N rows x cols=(intercept and k factors).
A = zeros(size(BR_factors_trimmed,1), 8); % create an empty matrix to store
 factor attributionex N rows x  cols

for t = 36:size(BR_factors_trimmed,1) % == 359
    LM = fitlm(BR_factors_trimmed(t-35:t,:),R_Base_t_reversed(t-35:t));
    b(t,:) = (LM.Coefficients.Estimate)';
    A(t,:) = [R_Base_t_reversed(t)-b(t,1)-BR_factors_trimmed(t,:)*b(t,2:end)',
 b(t,1), b(t,2:end).*BR_factors_trimmed(t,:)];
end
```

4.a. Plot betas with respect to time

```
% 4.a.
% Beta exposures first
figure(2);
subplot(3,2,1); plot(dateFactor(start_date+35:end),b(36:end,2));
 recessionplot; title('RealRates Beta'); grid on;
subplot(3,2,2); plot(dateFactor(start_date+35:end),b(36:end,3));
 recessionplot; title('Inflation Beta'); grid on;
subplot(3,2,3); plot(dateFactor(start_date+35:end),b(36:end,4));
 recessionplot; title('Credit beta'); grid on;
subplot(3,2,4); plot(dateFactor(start_date+35:end),b(36:end,5));
 recessionplot; title('Economic beta'); grid on;
subplot(3,2,5); plot(dateFactor(start_date+35:end),b(36:end,6));
 recessionplot; title('Emerging Mkt beta'); grid on;
```

```
subplot(3,2,6); plot(dateFactor(start_date+35:end),b(36:end,7));
 recessionplot; title('Liquidity beta'); grid on;
disp("The betas indicate significance of each factor to returns. If we look
 at the shaded area (recessions), we can see that the Economic factor becomes
 much more important, as does real rates. On the other hand, the importance
 of inflation and emerging markets drop drastically, as a reflection of the
 economic conditions of a recession.")
```

The betas indicate significance of each factor to returns. If we look at the shaded area (recessions), we can see that the Economic factor becomes much more important, as does real rates. On the other hand, the importance of inflation and emerging markets drop drastically, as a reflection of the economic conditions of a recession.

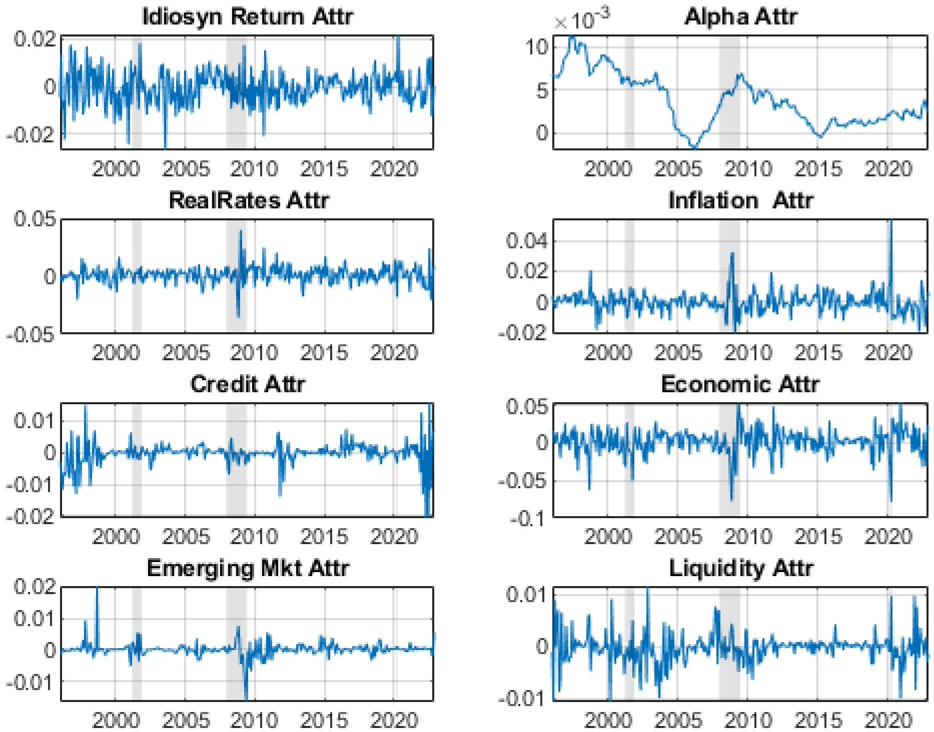


4.b. Monthly Return Attribution

```
% 4.b.
figure(3);
subplot(4,2,1); plot(dateFactor(start_date+35:end),A(36:end,1));
 recessionplot; title('Idiosyn Return Attr'); grid on;
subplot(4,2,2); plot(dateFactor(start_date+35:end),A(36:end,2));
 recessionplot; title('Alpha Attr'); grid on;
subplot(4,2,3); plot(dateFactor(start_date+35:end),A(36:end,3));
 recessionplot; title('RealRates Attr'); grid on;
subplot(4,2,4); plot(dateFactor(start_date+35:end),A(36:end,4));
 recessionplot; title('Inflation  Attr'); grid on;
```

```
subplot(4,2,5); plot(dateFactor(start_date+35:end),A(36:end,5));
 recessionplot; title('Credit Attr'); grid on;
subplot(4,2,6); plot(dateFactor(start_date+35:end),A(36:end,6));
 recessionplot; title('Economic Attr'); grid on;
subplot(4,2,7); plot(dateFactor(start_date+35:end),A(36:end,7));
 recessionplot; title('Emerging Mkt Attr'); grid on;
subplot(4,2,8); plot(dateFactor(start_date+35:end),A(36:end,8));
 recessionplot; title('Liquidity Attr'); grid on;
disp("The attribution plots show similar behavior around recessions, in
 regards to the importance of real rate and the economic factor. For both, we
 see a fall in attribution at the start of a recession and then a large spike
 upwards as a recovery begins. This fits with what we know of the business
 cycle and how a recession occures. Inflation displays the opposite pattern
 in its attribution plot, having a greater attribution value initially and
 then falling towards the end. This is probably reflective of the slowdown
 from a recession putting a dampener on the economy which makes inflation
 increasingly important, with the reverse happening during the recovery from a
 recession. ")
```

The attribution plots show similar behavior around recessions, in regards to the importance of real rate and the economic factor. For both, we see a fall in attribution at the start of a recession and then a large spike upwards as a recovery begins. This fits with what we know of the business cycle and how a recession occures. Inflation displays the opposite pattern in its attribution plot, having a greater attribution value initially and then falling towards the end. This is probably reflective of the slowdown from a recession putting a dampener on the economy which makes inflation increasingly important, with the reverse happening during the recovery from a recession.



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