Portfolio-Stress-Test (PortRisk)

PortRisk is a production-ready Python-based stress testing tool designed to evaluate portfolio risk under various stress scenarios. The portfolio can be a combination of spot and options. It leverages the Bloomberg API for data retrieval and offers a modular structure for customizable and flexible usage. The stress scenarios are designed to test for directionality, concentration, and dislocations of equity products. The stress parameters can be specified in JSON files by users.

For source code and implementation details, please refer to .\stress_testing\

For a set of predefined stress parameters, refer to ./stress_testing/examples/data/parameters/. User can define their parameters by updating the JSON files if needed.

For a high-level framework description, please read below. We mainly cover the stress testing framework for equity and equity derivatives which are more complex. Commodities (including cryptos) can easily fit into the framework after some modification. For example, country-level stress can be omitted for commodities.

1. Directionality

Directionality includes Macro and Sector stress which are all multilevel stress tests (a binary stress tree is being used).

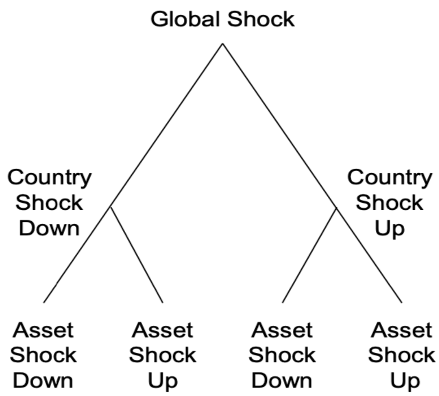
1.1. Macro

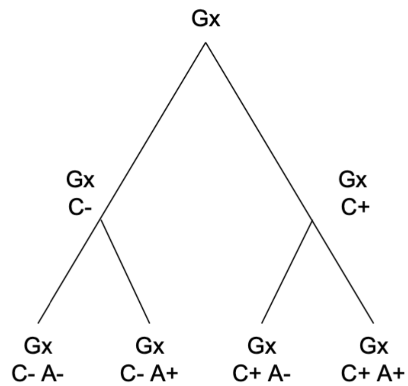
Macro Stress = Global + Country + Asset

Each asset is subject to shocks determined by three sequential levels of positive and negative stresses: global level, country dispersion level, and asset dispersion level. We refer to each shock level as a node.

- Global: Apply a global shock to all assets in the portfolio according to predefined parameters. For country groups 1-3, sum all losses and gains for each asset at the global shock level. For country group 4, sum only losses. Sum the Country 1-3 and Country 4 charges at the global level.
- Country Dispersions: At each global shock node (Gx), the asset is subject to a positive and negative country dispersion stress determined by the country in which the asset is incorporated. This acts as the second leg of the stress tree (see below Figure). At each global shock node (G), stress country up (C+) and country down (C-) to create the two country dispersion nodes (Gx, C+) and (Gx, C-). Apply Square Root of Sum of Squares (SRSS) by country.

- Asset Dispersions: At both country dispersion nodes, the asset is subject to positive and negative stresses. This creates four additional stress nodes Gx, C-, A-; Gx, C-, A+; Gx, C+, A-; and Gx, C+, A+





Apply SRSS for all assets. The greatest loss of these four nodes determines the effective stress level and the total charge for that asset.

The largest loss of Global + Country Dispersion + Asset Dispersion will be the dominant macro scenario.

1.2. Sector

Sector Stress= Global + Sector + Asset

Each asset is subject to shocks determined by three sequential levels of positive and negative stresses: global level, sector dispersion level and finally asset dispersion level. We refer to each shock level as a node. The sector stress is similar to the macro but the country-level dispersion is replaced with sector dispersion.

2. Concentration

Shock levels are determined by market cap (float only) and country of issuance of each company's stock. Positions are then grouped by issuing entity and for each entity, all position losses and gains are summed to give an entity-level Single/Seven Name Concentration loss. For single name, take the greatest single name concentration loss. For seven name, take the greatest losses from a market move in the same direction.

3. Dislocation

3.1. Relative Value – Spot Basis

Shock each security by the spot shock levels according to predefined parameters while holding volatility constant. Take the larger loss or zero for each security and sum losses for all underliers.

3.2. Relative Value – Volatility Basis

By expiry, shock the current implied volatility for each strike of each security by the shock levels according to predefined parameters while holding the spot constant. Vol moves are capped by predefined vol points. Take the larger loss or zero for each underlier and sum losses for all underliers (one number for IBM, one number for AAPL, etc)

3.3. Relative Value – Volatility Surface

Parameters like daily vega threshold, alpha, and beta, etc. can be found in
./stress_testing/examples/data/parameters/optconfig.json
Users can adjust the parameters when appropriate.

3.3.1. Parallel/Concentration

Account for Volatility fluctuations whilst the theoretical vega hedge is constructed.

Data: PositionVega, Expiry, atm_ivol_3m

Parameters: Daily Vega Thresholds, alpha_absolute, beta_absolute, alpha_relative, beta_relative

For each underlier, do step 1 to 3

Step 1: Calculate Days to trade (DDT) also called Days to Liquidate. Set this DDT=5 for vol-surface shocks if liquidity risk will not be considered.

a. Calculate 90 day net vega:

For each option:

```
vega_90days =  (90/TTX)**0.4 * PositionVega
```

Net the vega_90days for that underlier

b. DDT = 90 day net vega / 3m Daily Vega Threshold for that underlier

Remember that Days to Trade for concentration is defined at Asset Level.

Step 2: Calculate the shocks in vol points (Omega) which simulate implied vol movements during the DDT. Use this formula:

$$\omega = f(x) = \begin{cases} \alpha * (days\ to\ trade), & x \le 1 \\ \alpha * (days\ to\ trade)^{\beta}, & 1 < x < 30 \\ \alpha * (30)^{\beta}, & x \ge 30 \end{cases}$$

Two shocks (absolute and relative) are generated according to the TTD, alphas and betas. Remember for relative shock, multiply shock_r by atm_ivol_3m to get shock in vol points. Shock_r is just a percentage.

Take minimum of the Relative or Absolute shock. The vol level after the shock is to be within the range of Min and Max vol levels.

Step 3: Loss from parallel/concentration Shock

= 90 Days Vet Vega * Shocks in Vol Points (Omega) / 2

Omega/2 because it assumes that on average you only carry half the vega exposure, over the liquidation period to which you are exposed (given linear reduction). You are reducing vega exposure gradually from day 0 to day DTT, so the shock has a smaller impact for later days than earlier days.

Step 4: Across underliers, aggregate time to liquidate charges using the square root of the sum of squares.

Concentration and diversification.

3.3.2. Term Structure

Apply a term structure shock at each expiry by rotating the curve up and down around the 3-month expiry.

Data: For each expiry, we need PositionVega and atm_ivol (at the money implied volatility)

Parameters: Daily Vega Thresholds, alphas, betas

For any single underlier, do steps 1 to 3.

Step 1: Calculate Days to trade (DDT) also called Days to Liquidate for each expiry. Aggregate PositionVega by expiry:

```
Out[139]:
       Expiry  PositionVega
0  2020-06-12       -428407
1  2020-07-10       1301213
2  2020-08-14          -711
3  2020-09-11       -817942
4  2020-11-13       -329322
5  2020-12-11        285048
```

a. Calculate Weighted Vega Per Expiration Bucket (WVPEB): Interpolate each expiry to the relevant daily vega threshold buckets according to Time to Expiry (TTX).

TTX is calculated by expiry date – today. Remember the result can be sensitive to TTX. For near term options +-1 day TTX can make a big difference.

Eg. For TTX in 1m-3m bucket:

```
if (TTX > 30) and (TTX < 90):
WVPEB = (TTX-30)/60*3m_daily_vega_threshold + (90-TTX)/60*1m_daily_vega_threshold
```

b. DDT for each expiry = PositionVega for the expiry / WVPEB for the expiry

Results should be like this:

Out[139]:

	Expiry	PositionVega	DTT	TTX	WVPEB
0	2020-06-12	-428407	0.17308	11.00000	2,475,248.00000
1	2020-07-10	1301213	0.52569	39.00000	2,475,248.00000
2	2020-08-14	-711	0.00029	74.00000	2,475,248.00000
3	2020-09-11	-817942	0.33950	102.00000	2,409,241.33333
4	2020-11-13	-329322	0.15966	165.00000	2,062,706.33333
5	2020-12-11	285048	0.14660	193.00000	1,944,444.46111

Step 2: Calculate the shocks in vol points (Omega):

a. Set shock = 0 for 3 month expiry and shock near term down and long term up (vice versa). The shock for each expiry is calculated using the following formula:

$$\omega = f(x) = \begin{cases} \alpha * (days\ to\ trade), & x \leq 1 \\ \alpha * (days\ to\ trade)^{\beta}, & 1 < x < 30 \\ \alpha * (30)^{\beta}, & x \geq 30 \end{cases}$$

Interpolate each expiry to the relevant shock buckets according to TTX to get two shocks. The shock for the expiry is TTX distance weighted average shock. Remember to include 3m shock bucket which is 0. Eg.

```
if (TTX > 30) and (TTX < 90):
shock_absolute = (TTX-30)/60*0 + (90-TTX)/60*shock_absolute1m
shock_relative = (TTX-30)/60*0 + (90-TTX)/60*shock_relative1m
```

After this, results should look like this:

Out[139]:

	Expiry	PositionVega	DTT	TTX	WVPEB	shock_a	shock_r
0	2020-06-12	-428407	0.17308	11.00000	2,475,248.00000	-0.64904	-0.02942
1	2020-07-10	1301213	0.52569	39.00000	2,475,248.00000	-1.67564	-0.07596
2	2020-08-14	-711	0.00029	74.00000	2,475,248.00000	-0.00029	-0.00001
3	2020-09-11	-817942	0.33950	102.00000	2,409,241.33333	0.05704	0.00226
4	2020-11-13	-329322	0.15966	165.00000	2,062,706.33333	0.16764	0.00665
5	2020-12-11	285048	0.14660	193.00000	1,944,444.46111	0.18831	0.00744

Absolute shock is the actual shock in vol points. Relative shock should multiply at the money volatility to get shock in vol points (shock_r * atm_ivol).

b. Adjust the shocks by shock caps: Shock caps prevent upside shocks that would double implied vol and downside shocks that drive implied vol <5%. Remember for relative shock, use shock_r * atm_ivol which is shock in vol points. Shock_r is just a percentage.

Step 3: Loss from Term Structure Shock (also called Term Structure Charge or Time to Liquidate Charge from a margin perspective)

<u>= adjusted shock / 2 * PositionVega</u>

Step 4: Across underliers, aggregate time to liquidate charges using the square root of the sum of squares.

Notes: Days To Liq = Vega At Expiry / Vega Threshold

3.3.3. Skew

Shock the options based on the moneyness.

Data: For each option: Expiry, PositionVega, atm_ivol, Delta

Parameters: Daily Vega Thresholds, absolute and relative alpha beta for 1m, 6m, 1y, 2y etc

For each underlier, do steps 1 to 3

Step 1: Calculate Days to Trade (DDT) also called Days to Liquidate. The same as DDT calculation in Term Structure.

Out[142]:

	Expiry	PositionVega	Today	TTX	WVPEB	DTT
0	2020-08-14	-711	2020-06-01	74.00000	2,475,248.00000	0.00029
1	2020-12-11	285048	2020-06-01	193.00000	1,944,444.46111	0.14660
2	2020-07-10	1301213	2020-06-01	39.00000	2,475,248.00000	0.52569
3	2020-06-12	-428407	2020-06-01	11.00000	2,475,248.00000	0.17308
4	2020-11-13	-329322	2020-06-01	165.00000	2,062,706.33333	0.15966
5	2020-09-11	-817942	2020-06-01	102.00000	2,409,241.33333	0.33950

After calculation, allocate DDT back to each option. This allocation is only necessary for Skew shock not term structure. You can also do the allocation in the term structure shock as what GS's report is doing but this won't affect the results.

```
Out[141]:
     PositionVega      Expiry   Delta  atm_ivol  atm_ivol_3m           WVPEB     DTT       TTX
0           74658 2020-06-12 0.77000        22           22 2,475,248.00000 0.17308  11.00000
1          107586 2020-06-12 0.09000        22           22 2,475,248.00000 0.17308  11.00000
2          -15385 2020-06-12 1.00000        22           22 2,475,248.00000 0.17308  11.00000
3             852 2020-06-12 0.99000        22           22 2,475,248.00000 0.17308  11.00000
4            6942 2020-06-12 1.00000        22           22 2,475,248.00000 0.17308  11.00000
..            ...        ...     ...       ...          ...             ...     ...       ...
403         62963 2020-09-11 0.02000        22           22 2,409,241.33333 0.33950 102.00000
404        636643 2020-09-11 0.47000        22           22 2,409,241.33333 0.33950 102.00000
405         -4931 2020-09-11 0.06000        22           22 2,409,241.33333 0.33950 102.00000
406        -14729 2020-09-11 0.04000        22           22 2,409,241.33333 0.33950 102.00000
407        -51773 2020-09-11 0.05000        22           22 2,409,241.33333 0.33950 102.00000
```

Step 2: Calculate the shocks in vol points:

a. Calculate Omega using the formula:

$$\omega = f(x) = \begin{cases} \alpha * (days\ to\ trade), & x \leq 1 \\ \alpha * (days\ to\ trade)^{\beta}, & 1 < x < 30 \\ \alpha * (30)^{\beta}, & x \geq 30 \end{cases}$$

Note that we only have one pair of alpha and beta for an underlier, ie. One omega only. In term structure, we have two sets of alpha and beta (absolute and relative) for each expiry and omega is the shock in vol points.

b. Calculate Skew shock in vol points for each option: Multiply the implied volatility of the ATM option by distance of delta from 0.5 (ATM) and a shock charge (w):
= ATM implied vol * Omega / 2 * (0.5-|delta|)

The result should look like this:

```
Out[141]:
     PositionVega      Expiry   Delta  atm_ivol  atm_ivol_3m           WVPEB     DTT       TTX   Omega  SkewShockinVolPoints
0           74658 2020-06-12 0.77000        22           22 2,475,248.00000 0.17308  11.00000 0.02908              -0.08636
1          107586 2020-06-12 0.09000        22           22 2,475,248.00000 0.17308  11.00000 0.02908               0.13114
2          -15385 2020-06-12 1.00000        22           22 2,475,248.00000 0.17308  11.00000 0.02908              -0.15992
3             852 2020-06-12 0.99000        22           22 2,475,248.00000 0.17308  11.00000 0.02908              -0.15672
4            6942 2020-06-12 1.00000        22           22 2,475,248.00000 0.17308  11.00000 0.02908              -0.15992
..            ...        ...     ...       ...          ...             ...     ...       ...     ...                   ...
403         62963 2020-09-11 0.02000        22           22 2,409,241.33333 0.33950 102.00000 0.05704               0.30115
404        636643 2020-09-11 0.47000        22           22 2,409,241.33333 0.33950 102.00000 0.05704               0.01882
405         -4931 2020-09-11 0.06000        22           22 2,409,241.33333 0.33950 102.00000 0.05704               0.27606
406        -14729 2020-09-11 0.04000        22           22 2,409,241.33333 0.33950 102.00000 0.05704               0.28860
407        -51773 2020-09-11 0.05000        22           22 2,409,241.33333 0.33950 102.00000 0.05704               0.28233
```

ATM option has 0.5 delta. So, closer to ATM, smaller the skew shock.

Step 3: Loss from Skew Shock (also called Skew Charge or Time to Liquidate Charge from a margin perspective) for an underlier

= Sum(Skew Shock in Vol Points * PositionVega)

Step 4: Across underliers, aggregate time to liquidate charges using the square root of the sum of squares.