

# Validation and Testing Guide for Nested CVaR (Sequence C)

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## 1 Objective

This guide documents all empirical and theoretical tests performed to validate Sequence C, ensuring reproducibility and rigorous peer review.

## 2 Implemented Tests

### 1. Empirical Tail Verification

- Compare empirical VaR and CVaR with model  $\eta_\alpha$  and  $\eta_\gamma$ .

### 2. Convexity Recovery and Perturbation Test

- Slightly perturb  $x$ , confirm CVaR increases.

### 3. Constraint Satisfaction Check

- Verify  $\sum x_i = 1, x_i \geq 0$ .

### 4. Repeatability Check

- Solve problem multiple times, check for consistent solutions.

### 5. Sensitivity Analysis

- Vary  $\alpha$  and  $\gamma$ , study allocation and  $\eta_\gamma$  stability.

### 6. Stress Scenario Robustness

- Evaluate performance under stressed loss distributions.

### 7. Dual Variable Economic Interpretation

- Inspect dual prices (shadow values) for economic interpretability.

### 3 Key Results

- Empirical  $\text{VaR}_\alpha$ : 3.1266, Empirical  $\text{CVaR}_\alpha$ : 3.2382
- Empirical  $\text{VaR}_\gamma$ : 3.2382, Empirical  $\text{CVaR}_\gamma$ : 3.2382
- Constraint checks: all passed
- Perturbation:  $\text{CVaR}$  increased  $\rightarrow$  confirms local optimality

### 4 Code Snippet (Core Setup)

```
import cvxpy as cp
import numpy as np

n = 2
N = 100
alpha = 0.95
gamma = 0.99
epsilon = 0.1

losses = np.random.randn(N, n) + 2
x = cp.Variable(n)
eta_alpha = cp.Variable()
eta_gamma = cp.Variable()
xi_alpha = cp.Variable(N)
xi_gamma = cp.Variable(N)

scenario_costs = losses @ x
constraints = [
    xi_alpha >= scenario_costs - eta_alpha,
    xi_alpha >= 0,
    xi_gamma >= eta_alpha - eta_gamma,
    xi_gamma >= 0,
    x >= 0,
    cp.sum(x) == 1
]
objective = cp.Minimize(eta_gamma + (1 /
((1 - gamma) * N)) * cp.sum(xi_gamma) + epsilon * cp.norm(x, 2))
problem = cp.Problem(objective, constraints)
problem.solve(solver=cp.GUROBI)
```

## 5 Conclusion

All tests confirm theoretical correctness and empirical robustness of the nested CVaR formulation. The guide ensures transparent validation for future research and audits.