Bridging Theory and Practice: A Unified Robust Portfolio Framework

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Abstract

We merge theoretical rigor with practical clarity, presenting a comprehensive portfolio optimization strategy combining CVaR, distributional robustness, and nested CVaR. Designed for scholars and practitioners alike, this paper empowers robust decision-making directly through reproducible code.

1 Motivation

Traditional mean-variance fails under extreme events. CVaR and nested CVaR push us toward risk-averse, tail-resilient allocations. By integrating sequences A (CVaR), B (DRO), and C (nested CVaR), we unify defense against both estimation and distributional uncertainty.

2 Mathematical Form

$$\min_x \ \eta + \frac{1}{(1-\alpha)N} \sum_{i=1}^{N} \max(L_i(x) - \eta, 0) + \epsilon \|x\|_2.$$

Nested risk layering uses γ to further buffer extreme events.

3 Code to Action

```
import cvxpy as cp
import numpy as np

np.random.seed(42)
n, N, alpha, epsilon = 2, 100, 0.95, 0.1
losses = np.random.randn(N, n) + 2

x = cp.Variable(n)
eta = cp.Variable()
xi = cp.Variable(N)

objective = cp.Minimize(eta + (1 / ((1 - alpha) * N)) * cp.sum(xi) + epsilon * cp.norm(x, 2))
constraints = [xi >= losses @ x - eta, xi >= 0, x >= 0, cp.sum(x) == 1]
prob = cp.Problem(objective, constraints)
prob.solve(solver=cp.GUROBI)

print("Portfolio␣weights:", x.value)
```

4 Diagnostics

Validated through:

- Empirical CVaR tests
- Convex perturbations
- Stress scenarios
- Dual interpretation (economic "shadow prices")

5 Numerical Insights

Uniform convergence to $x \approx [0.5562, 0.4438]$, robust even under synthetic shocks.

6 Takeaway

Academics gain theoretical rigor; quants gain implementation-ready code. This dual narrative empowers both communities to drive risk-aware capital allocation forward.