Extended Appendix: Ultimate Compliance Scenario Engine Tests

A. Comprehensive Test Suite Overview

This appendix formalizes the advanced test suite designed to validate financial compliance scenario engines. Each module addresses distinct theoretical and empirical facets of model robustness.

B. Distributional Tests

Kolmogorov-Smirnov Test

$$D_{n,m} = \sup_x |F_n(x) - G_m(x)|$$

This non-parametric test evaluates whether two empirical distributions differ significantly.

Anderson-Darling Test

Weighted test emphasizing tail deviations, useful for stress testing where tail behavior is crucial.

Wasserstein Distance

Measures "earth mover's distance":

$$W_1(P, Q) = \inf_{\gamma \in \Gamma(P,Q)} \int |x - y| d\gamma(x, y)$$

C. Tail Dependence

Empirical upper tail dependence coefficient:

$$\lambda_U = \lim_{q \to 1^-} P(X > F_X^{-1}(q) \mid Y > F_Y^{-1}(q))$$

Estimates joint extreme co-movements beyond linear correlation.

D. Moment Tests

$$\text{Skewness} = \frac{\mathbb{E}[(X - \mu)^3]}{\sigma^3}, \quad \text{Kurtosis} = \frac{\mathbb{E}[(X - \mu)^4]}{\sigma^4} - 3$$

These higher moments capture asymmetry and tail fatness.

E. Nonlinear Sensitivity Analysis

Extended return function:

$$R_P^{\text{nonlin}} = w^\top F + v^\top (F \circ F) + u^\top (F \circ F \circ F)$$

Incorporates quadratic and cubic factor exposures.

F. Scenario Envelope Analysis

Amplified shocks:

$$F^{\text{env}} = \gamma \cdot F, \quad \gamma \gg 1$$

Used to explore theoretical limits beyond plausible regulatory bounds.

G. Surface Topology and Stress Surface

Visualizing:

$$R_P = f(F_1, F_2)$$

as a surface, reveals local minima, ridges, and vulnerability topologies.

H. Empirical Implementation Reproducibility

The implementation employs Python modules: `numpy`, `scipy`, `copulas`, `matplotlib`. All tests are implemented as modular functions enabling repeatable and auditable evaluations.

I. References

- McNeil, A.J., Frey, R., Embrechts, P. (2015). *Quantitative Risk Management.*
- Sklar, A. (1959). Copula functions.
- Basel Committee on Banking Supervision (2009). Stress testing guidelines.

J. Reproducibility Statement

All figures and metrics can be regenerated precisely with the included Python code, ensuring compliance with academic reproducibility standards and regulator audit trails.