

**TOWARD SUSTAINABLE VALUE CREATION:
ENVIRONMENTAL METRICS AND REGULATORY ENFORCEMENT IN THE
RECALIBRATION OF PROJECT FINANCE RISK MODELS**

Extended Abstract

Doctor of Business Administration (DBA) in Management and Technology

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1. RESEARCH AIM, MOTIVATION, AND RESEARCH GAP

Large-scale infrastructure projects are predominantly financed through non-recourse Project Finance structures, where bankability is assessed through the Debt Service Coverage Ratio (DSCR) family, the operative language of covenant compliance, distribution lock-ups, and refinancing conditions. Despite this centrality, prevailing practice computes the DSCR deterministically, treating individual risk drivers in isolation and failing to capture the joint behavior of environmentally material variables: carbon-regulatory costs, energy price dynamics, hydrologic stress, and supervisory enforcement. This gap is structurally important in the European context, where CSRD, EU Taxonomy, EBA/ECB guidance, and NGFS/TCFD frameworks increasingly require that climate and environmental risks be embedded in the analytical metrics used for financial decision-making, not merely in disclosures.

Three implementation gaps persist in the literature. First, scenario-based assessments rarely propagate transition- and physical-risk pathways to the specific economic levers (revenues, OPEX, CAPEX, financing schedules) that govern the DSCR. Second, advanced modeling setups frequently treat co-moving risk factors as independent, underestimating joint tail events: the simultaneous adverse alignment of demand, energy costs, hydrologic variables, and carbon-policy instruments is precisely the configuration generating the most severe solvency

deterioration. Third, the regulatory enforcement channel, comprising supervisory scrutiny, mandated remediation, and financial penalties, is rarely incorporated in a manner that preserves lender-grade metric definitions. This thesis addresses all three gaps.

2. FRAMEWORK AND METHODOLOGY

The proposed framework, designated DSCR-ER (Environmental- and Regulatory-adjusted DSCR), reformulates the coverage ratio as a scenario-conditional random variable. Contractual invariance is preserved: debt service remains fixed by financing agreements; what changes is the stochastic treatment of the drivers populating the CFADS waterfall, modeled jointly through a copula-based dependence structure and propagated through scenario-consistent transmission channels.

The architecture rests on three interlocking components. (i) A four-channel cash-flow decomposition models revenue risk, operating cost risk (energy and carbon-pricing exposure), CAPEX risk, and the financing channel (interest rates, tenor, and covenant architecture), with environmental materiality traceable from source data to output metric. (ii) A copula-based dependence structure, specifically Gaussian copulas and Vine copula specifications, captures the joint distribution of heterogeneous drivers (market, physical, and policy), separating marginal distributions from dependence and enabling flexible co-movement representation while preserving solvency metric definitions. The parsimony-versus-flexibility tradeoff between Gaussian and Vine specifications is governed by data availability and model governance requirements. (iii) Regulatory enforcement is treated as a discrete stochastic channel: expected penalties and mandated remediation outflows are parameterized through scenario-based frequencies and severities drawn from EBA/ECB supervisory guidance and introduced into

CFADS without altering the contractual structure of debt service. A Solvency Risk Ratio (SRR) summarizes the implied prudential reserve requirement at a given confidence level.

Calibration follows a three-tier data hierarchy (Tier A: observed; Tier B: derived; Tier C: synthetic/proxy), making all assumptions explicit, auditable, and sensitivity-testable. Uncertainty propagation is implemented via Monte Carlo simulation. A complementary geometric object, the solvency surface or Omega-frontier, maps parameter combinations on the boundary of covenant compliance, providing a natural interface between stochastic model outputs and the binary decision logic of credit committees.

3. EMPIRICAL APPLICATION AND HYPOTHESES

The framework is illustrated using two Spanish concession assets with contrasting environmental profiles. The Barcelona Llobregat desalination plant (ATLL), exposed to hydrologic stress, energy price dynamics, and environmental compliance enforcement, serves as the primary experimental setting, calibrated using ERA5 reanalysis and NGFS-consistent transition paths.

The Madrid M-45 shadow-toll motorway, exposed primarily to demand and road-transport decarbonization policy, functions as a controlled benchmark. The central hypothesis is that assets appearing robust under deterministic appraisal exhibit material probabilities of covenant erosion once joint stress across demand, cost, physical, and regulatory channels is modeled through explicit dependence structures, a joint-stress effect that is structurally unobservable under conventional sensitivity analysis. A further hypothesis is that DSCR-ER tail risk severity is conditioned by financial structure: leverage, cost rigidity, and covenant architecture determine baseline exposure, while environmental drivers operate as amplifiers.

4. CONTRIBUTIONS, LIMITATIONS, AND FUTURE RESEARCH

The primary academic contribution is the structured integration of infrastructure finance, climate-risk scenario analysis, copula-based dependence modeling, and supervisory guidance within a contract-faithful, audit-ready solvency architecture. Practically, the DSCR-ER framework enables early identification of latent downside risks, structural integration of financial and ESG risk functions, and efficiency gains in credit decision workflows. The Tier A/B/C governance architecture and reproducible computational stack are designed as deployable templates, scalable across asset classes and jurisdictions, and adoptable by credit committees, supervisory bodies, and multilateral development banks without bespoke reengineering. Limitations include proxy reliance on Tier C assumptions, two-asset single-jurisdiction empirical scope, and EU-first regulatory framing. Future research directions include portfolio-level application, dynamic dependence specifications, expanded Vine structures, and integration with regulatory capital frameworks.

SELECTED REFERENCES

- Aas, K., Czado, C., Frigessi, A., & Bakken, H. (2009). *Pair-copula constructions of multiple dependence. Insurance: Mathematics and Economics*, 44(2), 182-198.
<https://doi.org/10.1016/j.insmatheco.2007.02.001>
- Ehlers, T., Packer, F., & De Greiff, K. (2022). *The pricing of carbon risk in syndicated loans: Which risks are priced and why? Journal of Banking and Finance*, 136, Article 106180.
<https://doi.org/10.1016/j.jbankfin.2021.106180>
- European Banking Authority. (2021). *EBA report on management and supervision of ESG risks for credit institutions and investment firms (EBA/REP/2021/18)*.
<https://www.eba.europa.eu/publications-and-media/press-releases/eba-publishes-its-report-management-and-supervision-esg-risks>

European Central Bank. (2022). *Walking the talk: Banks responses to climate risks*.

<https://www.bankingsupervision.europa.eu/ecb/pub/pdf/ssm.thematicreviewcerreport112022~2eb322a79c.en.pdf>

European Environment Agency. (2024). *European climate risk assessment (EEA Report No 01/2024)*. Publications Office of the European Union.

<https://www.eea.europa.eu/en/analysis/publications/european-climate-risk-assessment>

European Commission. (2023). *Regulation (EU) 2023/956 establishing a carbon border adjustment mechanism*. Official Journal of the European Union, L 130, 52-104.

<https://eur-lex.europa.eu/eli/reg/2023/956/oj/eng>

European Financial Reporting Advisory Group. (2023). *ESRS Set 1: European Sustainability Reporting Standards*. EFRAG. <https://xbrl.efrag.org/e-esrs/esrs-set1-2023.html>

European Parliament, & Council of the European Union. (2022). *Directive (EU) 2022/2464 as regards corporate sustainability reporting*. Official Journal of the European Union, L 322, 15-80. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32022L2464>

Gatti, S. (2023). *Project finance in theory and practice (3rd ed.)*. Academic Press.

<https://www.sciencedirect.com/book/monograph/9780323983600/project-finance-in-theory-and-practice>

Glasserman, P. (2004). *Monte Carlo methods in financial engineering*. Springer.

<https://link.springer.com/book/10.1007/978-0-387-21617-1>

Intergovernmental Panel on Climate Change. (2022). *Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the IPCC*. Cambridge University Press. <https://doi.org/10.1017/9781009325844>

Lu, M., Chen, C. Y., & Hardle, W. K. (2017). Copula-based factor model for credit risk analysis. *Review of Quantitative Finance and Accounting*, 49(4), 949-971.

<https://doi.org/10.1007/s11156-016-0613-x>

Nelsen, R. B. (2006). *An introduction to copulas* (2nd ed.). Springer.

<https://link.springer.com/book/10.1007/0-387-28678-0>

NGFS. (2024). NGFS climate scenarios for central banks and supervisors. Network for Greening the Financial System. [https://www.ngfs.net/en/publications-and-](https://www.ngfs.net/en/publications-and-statistics/publications/ngfs-climate-scenarios-central-banks-and-supervisors)

[statistics/publications/ngfs-climate-scenarios-central-banks-and-supervisors](https://www.ngfs.net/en/publications-and-statistics/publications/ngfs-climate-scenarios-central-banks-and-supervisors)

TCFD. (2017). *Recommendations of the Task Force on Climate-related Financial Disclosures*.

<https://assets.bbhub.io/company/sites/60/2021/10/FINAL-2017-TCFD-Report.pdf>

Vicente-Serrano, S. M., Begueria, S., & Lopez-Moreno, J. I. (2010). A multiscalar drought index sensitive to global warming. *Journal of Climate*, 23(7), 1696-1718.

<https://doi.org/10.1175/2009JCLI2909.1>

Yescombe, E. R. (2002). *Principles of project finance*. Academic Press.

<https://www.sciencedirect.com/book/monograph/9780127708515/principles-of-project-finance>