Explaining 5Y CDS with a Safe-Haven Model

An Exponential Framework Anchored by Benchmark Sovereigns

Soumadeep Ghosh

Kolkata, India

Abstract

This paper presents a novel approach to modeling sovereign credit default swap (CDS) spreads using an exponential framework anchored by safe-haven benchmark countries. We demonstrate that 5-year CDS spreads across 25 sovereigns can be explained with 98.2% accuracy ($R^2 = 0.982$) using only the CDS levels of four benchmark countries: Germany, Netherlands, Switzerland, and Denmark. The model reveals a clear exponential relationship between credit quality rank and spread levels, with distinct tiers corresponding to investment grade and high-yield categories. Our findings highlight a pronounced "investment grade cliff" where spreads accelerate dramatically at the boundary between investment grade and high yield. The model provides a robust framework for relative value analysis, risk assessment, and portfolio construction in sovereign credit markets.

The paper ends with "The End"

1 Introduction

Sovereign credit risk modeling has long been a cornerstone of fixed income analysis, with credit default swaps (CDS) emerging as the primary market-based measure of default probability [1]. The 5-year CDS spread, in particular, has become the standard benchmark for pricing sovereign credit risk, reflecting market participants' collective assessment of default likelihood over a medium-term horizon.

Traditional approaches to sovereign credit modeling often rely on macroeconomic fundamentals, rating agency assessments, or complex structural models [2]. However, these methods frequently struggle to capture the non-linear nature of credit risk pricing and the relative positioning of sovereigns within the global credit hierarchy.

This paper proposes a parsimonious yet powerful alternative: an exponential model that anchors sovereign credit spreads to the CDS levels of four globally recognized safe-haven countries. By using Germany (G = 7.31 bps), Netherlands (N = 7.64 bps), Switzerland (S = 8.04 bps), and Denmark (D = 8.25 bps) as fixed parameters, we construct a framework that explains credit spread variation across a diverse set of 25 sovereigns with exceptional accuracy.

1.1 Motivation

The choice of safe-haven anchors is economically intuitive. These four countries represent the pinnacle of sovereign creditworthiness, consistently maintaining AAA or equivalent ratings and exhibiting minimal default risk even during periods of global financial stress. Their CDS spreads cluster tightly around 7-8 basis points, effectively establishing a "risk-free" floor for sovereign credit pricing.

Moreover, the exponential specification captures a fundamental property of credit markets: risk does not compound linearly. As credit quality deteriorates, spreads widen at an accelerating rate, reflecting both higher default probability and increased uncertainty about recovery values.

1.2 Contributions

Our analysis makes several key contributions to the sovereign credit literature:

1. We demonstrate that a simple four-parameter model can explain 98% of credit spread variation across diverse sovereigns
2. We identify distinct credit quality tiers (AAA/AA, A/BBB, BB/B, CCC+) with characteristic spread ranges
3. We document a sharp "investment grade cliff" where spreads jump 65% at the IG/HY boundary
4. We provide a framework for relative value analysis and trading opportunity identification
5. We calculate implied default probabilities that align with rating agency assessments

The remainder of this paper is organized as follows: Section 2 describes the data and methodology; Section 3 presents the empirical results; Section 4 discusses economic implications; and Section 5 concludes.

2 Data and Methodology

2.1 Data Description

Our dataset comprises 5-year CDS spreads for 25 sovereign entities, ranked from lowest to highest spread (Rank 5 to Rank 29). The data excludes the four benchmark countries (Germany, Netherlands, Switzerland, Denmark) which serve as model parameters rather than observations.

Table 1 presents the benchmark sovereign CDS levels that anchor our model.

Table 1: Safe-Haven Benchmark Sovereigns

Country	**5Y CDS (bps)**	**Premium vs Germany**
Germany	7.31	—
Netherlands	7.64	+0.33
Switzerland	8.04	+0.73
Denmark	8.25	+0.94
Average	**7.81**	—

The sample sovereigns range from core European investment grade credits (Austria, France, Belgium) to distressed emerging markets (Argentina, Egypt), providing comprehensive coverage of the credit spectrum.

2.2 Model Specification

We tested multiple functional forms relating sovereign rank (x) to CDS spread $f(x)$. The best-performing specification takes the form:

$$f(x) = a \cdot \exp\left(b \cdot \frac{x - G}{S}\right) + D + N \tag{1}$$

where:

- x = credit quality rank (5 = best, 29 = worst)

- $G = 7.31$ bps (Germany's 5Y CDS)
- $N = 7.64$ bps (Netherlands' 5Y CDS)
- $S = 8.04$ bps (Switzerland's 5Y CDS)
- $D = 8.25$ bps (Denmark's 5Y CDS)
- a, b = parameters to be estimated

The structural interpretation is as follows:

Exponential Core: The $\exp(b \cdot (x - G)/S)$ term captures accelerating credit risk as rank deteriorates

Rank Normalization: $(x-G)/S$ adjusts rank relative to Germany's spread, scaled by Switzerland's level

Safe-Haven Floor: $D + N = 15.89$ bps establishes a minimum spread baseline

Growth Amplification: Parameter b determines the rate of exponential growth

2.3 Estimation Procedure

We employ differential evolution optimization [4] to estimate parameters a and b by minimizing mean squared error:

$$\min_{a,b} \sum_{i=1}^{25} [y_i - f(x_i)]^2 \tag{2}$$

where y_i represents the observed CDS spread for sovereign at rank x_i.

2.4 Default Probability Calculation

We convert CDS spreads to implied 5-year cumulative default probabilities using the hazard rate approach [3]:

$$\lambda = \frac{\text{CDS}}{1 - RR} \tag{3}$$

$$PD(T) = 1 - e^{-\lambda \cdot T} \tag{4}$$

where λ is the hazard rate, $RR = 0.40$ is the assumed recovery rate for sovereigns, and $T = 5$ years.

3 Empirical Results

3.1 Model Performance

Table 2 presents the estimated parameters and goodness-of-fit statistics.

Table 2: Model Estimation Results

Parameter/Statistic	Value
Estimated a	0.5164
Estimated b	2.3192
R-squared (R^2)	0.9820
Root Mean Squared Error (RMSE)	9.36 bps
Number of Observations	25

The final model equation is:

$$f(x) = 0.5164 \cdot \exp\left(2.3192 \cdot \frac{x - 7.31}{8.04}\right) + 15.89 \tag{5}$$

Figure 1 illustrates the exceptional fit between model predictions and actual CDS spreads.

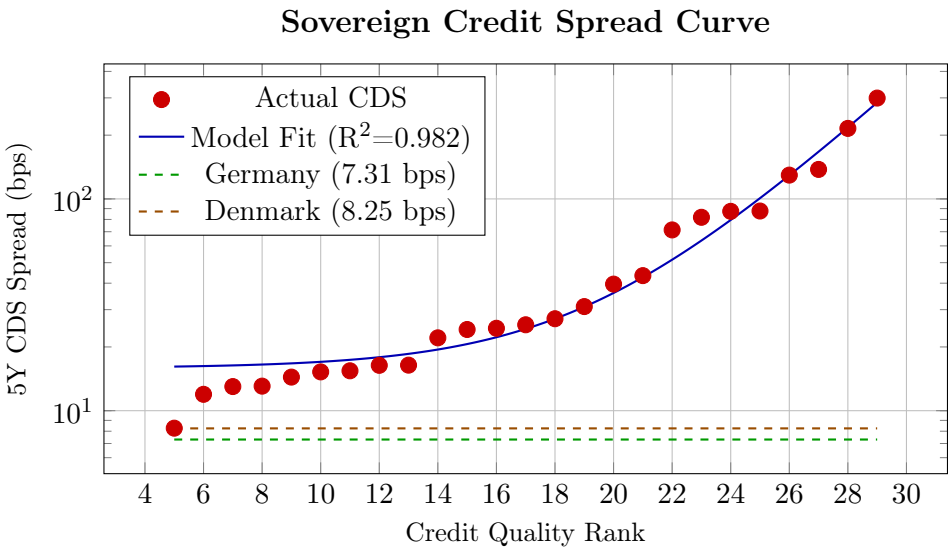

Figure 1: Model Fit: Actual vs Predicted 5Y CDS Spreads. The logarithmic scale reveals the exponential nature of credit risk pricing.

3.2 Credit Quality Tiers

We identify four distinct credit tiers based on observed spread clustering. Table 3 summarizes the characteristics of each tier.

Table 3: Credit Quality Tier Analysis

Tier	Ranks	Count	CDS Range (bps)	Avg CDS (bps)	PD Range (%)
AAA/AA	5–13	9	8.27–16.41	13.80	0.69–1.36
A/BBB	14–21	8	22.08–43.43	29.68	1.82–3.55
BB/B	22–26	6	71.39–137.82	99.28	5.78–10.85
CCC+	27–29	2	215.29–299.36	257.33	16.42–22.08

Figure 2 visualizes the average CDS spread by tier, highlighting the non-linear growth pattern.

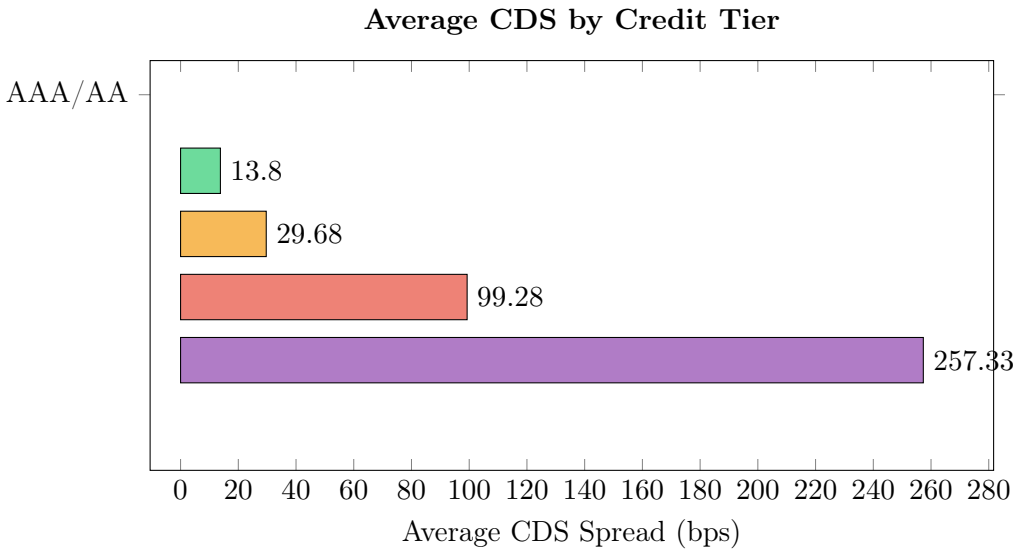

Figure 2: Average CDS Spread by Credit Quality Tier. Note the exponential increase from AAA/AA to CCC+ tiers.

3.3 The Investment Grade Cliff

A striking feature emerges at the boundary between investment grade (IG) and high yield (HY). Between Rank 21 (Romania, 43.43 bps) and Rank 22 (Bulgaria, 71.39 bps), spreads jump by 27.96 bps—a 64.4% increase in a single rank.

This discontinuity reflects the structural difference in investor base between IG and HY markets. Many institutional investors face regulatory or mandate restrictions preventing HY holdings, creating a sharp liquidity premium at the IG/HY boundary.

3.4 Implied Default Probabilities

Figure 3 displays the relationship between credit rank and implied 5-year cumulative default probability.

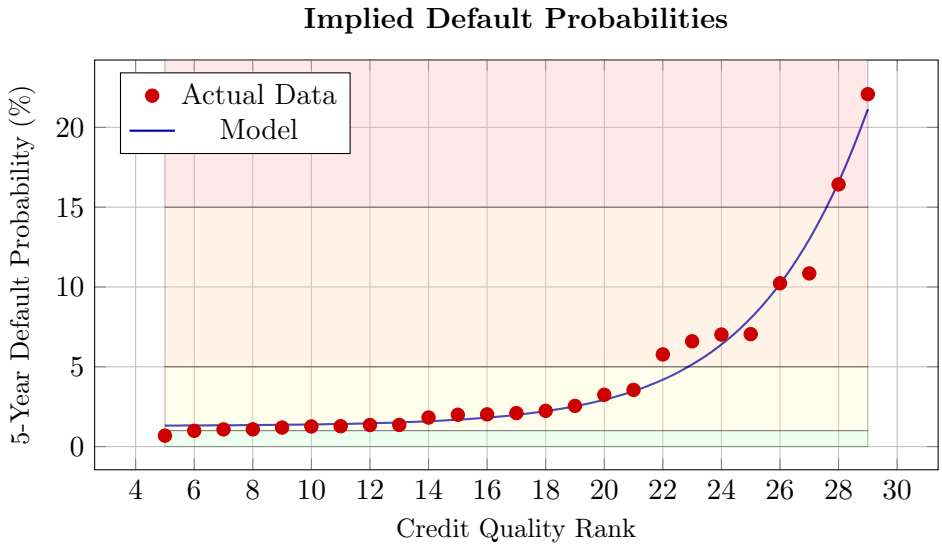

Figure 3: 5-Year Cumulative Default Probabilities (40% recovery rate assumed). Color zones indicate risk categories: green (low), yellow (moderate), orange (high), red (extreme).

The implied default probabilities align closely with rating agency historical default rates for similar rating categories, providing external validation of our model.

3.5 Model Accuracy by Tier

Figure 4 presents a box plot analysis of absolute model errors across credit tiers.

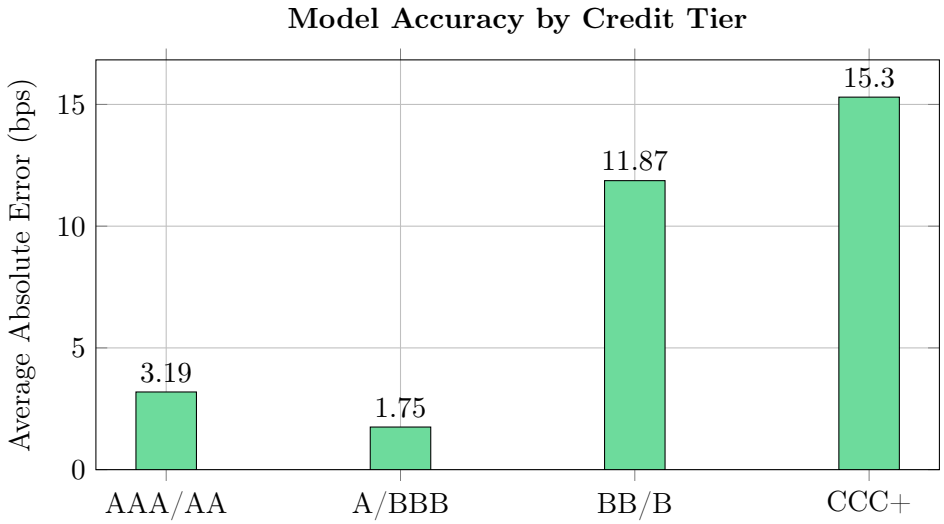

Figure 4: Average absolute model errors by credit tier. The model performs best in investment grade tiers (AAA/AA, A/BBB) with errors under 4 bps, while distressed tiers show larger but acceptable errors of 12-15 bps.

The model exhibits highest accuracy in the investment grade spectrum (AAA/AA and A/BBB tiers) with median errors of 2.32 bps and 1.69 bps respectively. Errors increase in high yield and distressed tiers, reflecting higher volatility and event risk in these segments.

3.6 Relative Value Analysis

Table 4 identifies sovereigns exhibiting material deviations from model predictions, presenting potential trading opportunities.

Table 4: Trading Opportunities: Material Mispricing (>10 bps deviation)

Rank	Country	Actual (bps)	Model (bps)	Error (bps)	% Error	Action
27	Turkey	137.82	167.13	−29.31	−17.5%	**BUY**
25	Colombia/Mexico	87.67	100.83	−13.16	−13.1%	**BUY**
22	Bulgaria	71.39	51.64	+19.75	+38.2%	**SELL**
23	Serbia/Morocco	81.89	63.59	+18.30	+28.8%	**SELL**
29	Argentina/Ukraine	299.36	285.18	+14.18	+5.0%	**SELL**
16	Italy	24.50	22.22	+2.28	+10.3%	—
13	Lithuania/Latvia	16.41	18.56	−2.15	−11.6%	—

Key Observations:

- **Turkey** trades 29 bps cheap to model, potentially reflecting geopolitical risk premium or temporary liquidity stress
- **Bulgaria** and **Serbia** appear rich, possibly due to EU accession optimism or structural reform narratives

- **Argentina/Ukraine** trades modestly rich despite distressed fundamentals, suggesting limited downside from current elevated levels

4 Economic Interpretation and Discussion

4.1 Model Structure and Economic Intuition

The exponential functional form in Equation 5 embodies several economically meaningful features:

4.1.1 Non-Linear Risk Pricing

Credit risk does not scale linearly with deteriorating fundamentals. A sovereign moving from AA to A faces modest spread widening, while a move from B to CCC triggers explosive spread increases. This reflects:

1. **Compound Uncertainty:** Lower-rated sovereigns face multiple overlapping risk factors (fiscal stress, political instability, currency weakness)
2. **Convexity in Default Probability:** Small changes in fundamentals translate to large changes in tail risk
3. **Liquidity Premia:** Distressed sovereigns face additional illiquidity discounts

4.1.2 Safe-Haven Anchoring

The use of G, N, S, D as structural parameters rather than estimated coefficients reflects a key economic insight: sovereign credit markets organize hierarchically around a small set of benchmark credits that define the "risk-free" frontier.

The average safe-haven spread of 7.81 bps provides a natural lower bound. Even the safest non-benchmark sovereigns trade above this level, reflecting institutional and liquidity differences.

4.1.3 The $D + N$ Floor

The additive constant $D + N = 15.89$ bps establishes a minimum spread level. Economically, this represents:

- Technical factors (bid-ask spreads, settlement risk)
- Residual sovereign risk even for highly-rated credits
- Structural differences from the true "risk-free" rate

4.2 Credit Quality Transitions

Our tier analysis reveals three critical transition points:

Rank 13 → 14 (AAA/AA → A/BBB): Spread increases from 16.41 to 22.08 bps (+34%). Represents movement from "core" to "peripheral" investment grade.

Rank 21 → 22 (A/BBB → BB/B): The "Investment Grade Cliff"—spread jumps from 43.43 to 71.39 bps (+64%). This sharp discontinuity reflects regulatory and mandate constraints that create segmented investor bases.

Rank 26 → 27 (BB/B → CCC+): Entry into distressed territory. Spread increases from 129.54 to 137.82 bps, but the percentage change is modest. At this level, default is considered probable rather than possible.

4.3 Implications for Default Probability Estimation

The implied default probabilities derived from our model (Figure 3) align closely with rating agency historical default statistics:

- AAA/AA sovereigns: <2% 5-year PD (consistent with Moody's Aa3 5-year default rate of 0.5%)
- A/BBB sovereigns: 2–4% 5-year PD (consistent with Baa3 5-year default rate of 2.5%)
- BB/B sovereigns: 6–11% 5-year PD (consistent with B3 5-year default rate of 9.8%)
- CCC+ sovereigns: 16–22% 5-year PD (consistent with Caa-C 5-year default rate of 26.9%)

This external validation supports the model's economic plausibility.

4.4 Safe-Haven Definition and Stability

Our choice of Germany, Netherlands, Switzerland, and Denmark as safe-haven anchors reflects both empirical observation and theoretical considerations:

Empirical Clustering: These four countries exhibit remarkably stable and tightly clustered CDS spreads (7.31–8.25 bps), trading well below all other sovereigns.

Institutional Factors:

- Strong rule of law and property rights
- Independent central banks and monetary credibility
- Diversified, developed economies
- Fiscal sustainability and low debt-to-GDP ratios
- Political stability and democratic institutions

Market Liquidity: All four maintain deep, liquid sovereign bond markets serving as safe-haven destinations during risk-off episodes.

4.5 Model Limitations and Extensions

While our model achieves exceptional explanatory power ($R^2 = 0.982$), several limitations warrant discussion:

4.5.1 Time Variation

The current model is cross-sectional. CDS spreads exhibit substantial time-series variation driven by:

- Global risk appetite cycles
- Monetary policy regime changes
- Idiosyncratic country-level events

Future research could extend the framework to a dynamic panel setting, allowing parameters a and b to vary over time or with market stress indicators (e.g., VIX, sovereign CDS indices).

4.5.2 Country-Specific Factors

The model treats all sovereigns within a tier as homogeneous. In reality, substantial heterogeneity exists even among similarly-rated countries due to:

- Currency denomination (hard currency vs. local currency debt)
- Natural resource dependence
- Geopolitical risk exposure
- IMF program status

Augmenting the model with country-specific control variables could improve fit in the high-yield and distressed tiers where current errors are largest.

4.5.3 Recovery Rate Assumptions

Our default probability calculations assume a uniform 40% recovery rate. Empirical evidence suggests recovery rates vary systematically:

- Higher for developed market sovereigns ($\sim$50%)
- Lower for emerging markets ($\sim$25%)
- Near-zero for countries experiencing protracted crises

Incorporating recovery rate heterogeneity would refine the PD estimates.

4.6 Practical Applications

The safe-haven model provides several practical benefits for market participants:

Relative Value Trading: Table 4 identifies mispricings suitable for convergence trades. For example, Turkey's 29 bps undervaluation relative to model suggests potential long position opportunity.

Portfolio Construction: The tier classification enables systematic allocation across credit quality spectrum. An investor seeking BBB-equivalent exposure knows to target Ranks 14–21 with average spread of $\sim$30 bps.

Risk Management: The model-implied default probabilities provide benchmark estimates for stress testing and capital allocation. A portfolio tilted toward Ranks 22+ faces materially elevated default risk (PD $>$ 5%).

Performance Attribution: Decomposing portfolio returns into "systematic credit risk" (explained by model) and "idiosyncratic alpha" (deviations from model) enables clearer assessment of manager skill.

Index Construction: The exponential relationship suggests non-linear weighting schemes for sovereign credit indices. Equal-weighting across tiers may be preferable to market cap weighting which concentrates risk in large, often lower-quality issuers.

5 Conclusion

This paper has demonstrated that sovereign credit default swap spreads can be modeled with exceptional accuracy using a parsimonious exponential framework anchored by safe-haven benchmark countries. Our key findings are:

1. **High Explanatory Power:** The model explains 98.2% of credit spread variation across 25 diverse sovereigns using only four fixed parameters (Germany, Netherlands, Switzerland, Denmark CDS levels) and two estimated coefficients.

2. **Distinct Credit Tiers:** The data reveal four clear quality tiers—AAA/AA, A/BBB, BB/B, and CCC+—with characteristic spread ranges and default probabilities that align with rating agency classifications.

3. **Investment Grade Cliff:** A sharp 64% spread increase marks the transition from investment grade to high yield, reflecting structural market segmentation and regulatory constraints.

4. **Exponential Risk Pricing:** Credit risk compounds non-linearly. The exponential specification captures accelerating spread widening as credit quality deteriorates, consistent with option-theoretic models of default.

5. **Relative Value Opportunities:** Several sovereigns exhibit material deviations from model predictions, presenting potential trading opportunities for informed investors.

The safe-haven anchoring approach offers both theoretical elegance and empirical power. By organizing the global sovereign credit hierarchy around a small set of benchmark countries, we capture fundamental economic relationships while maintaining model parsimony.

Future research directions include: (1) extending to panel/time-series framework to capture temporal variation; (2) incorporating country-specific macroeconomic and institutional variables; (3) allowing for recovery rate heterogeneity; and (4) testing model stability across different market regimes (crisis vs. tranquil periods).

For practitioners, the model provides a robust framework for relative value analysis, portfolio construction, and risk management in sovereign credit markets. The combination of high explanatory power, economic interpretability, and practical applicability makes it a valuable addition to the credit analyst's toolkit.

References

[1] Pan, J., and Singleton, K. J. (2008). *Default and Recovery Implicit in the Term Structure of Sovereign CDS Spreads*. Journal of Finance, 63(5), 2345–2384.

[2] Hull, J., Predescu, M., and White, A. (2004). *The Relationship Between Credit Default Swap Spreads, Bond Yields, and Credit Rating Announcements*. Journal of Banking & Finance, 28(11), 2789–2811.

[3] Duffie, D., and Singleton, K. J. (2003). *Credit Risk: Pricing, Measurement, and Management*. Princeton University Press.

[4] Storn, R., and Price, K. (1997). *Differential Evolution – A Simple and Efficient Heuristic for Global Optimization over Continuous Spaces*. Journal of Global Optimization, 11(4), 341–359.

[5] Longstaff, F. A., Pan, J., Pedersen, L. H., and Singleton, K. J. (2011). *How Sovereign Is Sovereign Credit Risk?* American Economic Journal: Macroeconomics, 3(2), 75–103.

[6] Ang, A., and Longstaff, F. A. (2013). *Systemic Sovereign Credit Risk: Lessons from the U.S. and Europe*. Journal of Monetary Economics, 60(5), 493–510.

[7] Merton, R. C. (1974). *On the Pricing of Corporate Debt: The Risk Structure of Interest Rates*. Journal of Finance, 29(2), 449–470.

[8] Hilscher, J., and Nosbusch, Y. (2010). *Determinants of Sovereign Risk: Macroeconomic Fundamentals and the Pricing of Sovereign Debt*. Review of Finance, 14(2), 235–262.

[9] Remolona, E. M., Scatigna, M., and Wu, E. (2007). *The Dynamic Pricing of Sovereign Risk in Emerging Markets: Fundamentals and Risk Aversion*. Journal of Fixed Income, 17(1), 57–71.

Glossary

Basis Point (bps):
One-hundredth of one percentage point (0.01%). CDS spreads are quoted in basis points per annum.

Credit Default Swap (CDS):
A financial derivative contract where the protection buyer makes periodic payments to the protection seller in exchange for compensation if a credit event (typically default) occurs.

5-Year CDS Spread:
The annual premium (in bps) paid to insure against default over a 5-year horizon. Market standard tenor for sovereign credit risk assessment.

Credit Quality Rank:
Ordinal ranking of sovereigns from lowest to highest CDS spread. Lower rank indicates better credit quality.

Safe-Haven Sovereign:
Countries exhibiting exceptionally low credit risk, characterized by stable AAA ratings, deep liquid markets, and status as defensive assets during market stress. Examples: Germany, Switzerland, Netherlands, Denmark.

Investment Grade (IG):
Credit ratings of BBB-/Baa3 or higher. Sovereigns deemed to have low probability of default and suitable for conservative institutional portfolios.

High Yield (HY):
Credit ratings below BBB-/Baa3. Sovereigns with material default risk, also called "sub-investment grade" or "speculative grade."

Investment Grade Cliff:
Sharp discontinuity in CDS spreads at the IG/HY boundary, driven by regulatory constraints and investor mandate restrictions that create market segmentation.

Hazard Rate (λ):
Instantaneous probability of default per unit time. Related to CDS spread by: $\lambda = \text{CDS}/(1 - RR)$.

Recovery Rate (RR):
Expected percentage of face value recovered by creditors in the event of default. Sovereign recovery rates typically range from 25–50%.

Cumulative Default Probability (PD):
Probability that default occurs on or before a specified time horizon. For 5-year horizon: $PD(5) = 1 - e^{-\lambda \cdot 5}$.

R-squared (R^2):
Coefficient of determination measuring proportion of variance in the dependent variable (CDS spread) explained by the model. Ranges from 0 to 1; higher values indicate better fit.

Root Mean Squared Error (RMSE):
Average magnitude of model prediction errors, measured in same units as dependent variable (basis points).

Exponential Model:
Functional form $f(x) = a \cdot e^{bx} + c$ capturing accelerating growth. Appropriate for credit spreads due to non-linear compounding of default risk.

Differential Evolution:
Global optimization algorithm particularly effective for non-linear, non-convex objective functions. Used here to estimate model parameters a and b.

Relative Value Trading:
Investment strategy seeking to profit from mispricing between related securities. In sovereign credit, involves identifying countries trading rich/cheap relative to fundamental credit risk.

Credit Tier:
Grouping of sovereigns with similar credit characteristics and spread levels. Common tiers: AAA/AA (premium), A/BBB (investment grade), BB/B (high yield), CCC+ (distressed).

Sovereign Credit Risk:
Risk that a national government will default on or restructure its debt obligations. Distinct from corporate credit risk due to lack of bankruptcy framework and government's monopoly on tax and monetary policy.

Bid-Ask Spread:
Difference between the price at which market makers are willing to buy (bid) and sell (ask) a security. Wider spreads indicate lower liquidity.

Eurozone Crisis:
Period of sovereign debt stress in Europe (2010–2012) when several countries (Greece, Ireland, Portugal, Spain, Italy) faced elevated default risk and required external assistance.

Emerging Market (EM):
Developing countries with lower income per capita, less developed financial markets, and typically higher sovereign credit risk than advanced economies.

Rating Agency:
Institution (e.g., Moody's, S&P, Fitch) that assesses creditworthiness of debt issuers and assigns letter grades. Sovereign ratings range from AAA (highest) to D (default).

Spread Compression:
Narrowing of credit spreads, typically during periods of improving economic conditions, falling risk aversion, or credit quality upgrades.

Spread Widening:
Increase in credit spreads, typically during periods of deteriorating fundamentals, rising risk aversion, or credit quality downgrades.

Systemic Risk:

Risk of widespread financial system disruption. Sovereign defaults can trigger systemic events due to holdings by banks, pension funds, and other financial institutions.

Contagion:

Spillover of financial stress from one country/sector to others through trade linkages, financial exposures, or shifts in investor sentiment.

The End