A Structural Model for Sovereign Credit Risk

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Introduction
Introduction

Outline

- Motivation and goal of this research
- A brief overview of the literature
- The main results at a glance
- A snapshot of the model
- Main results
  - Theoretical predictions of the relationship between credit risk and macro-variables
  - Explanation of the time variation in credit risk
- Conclusion
Introduction

Motivation

Stylized facts

- Sovereign debt constitutes the largest asset class in emerging markets
  - $5,500bn of principal in 2007
- Sovereign debt has been at the center of several international lending crises
- We need to evaluate how developing country creditworthiness varies over time
  - Country risk rating agencies, financial institutions, and the financial market in general
Introduction

Motivation and main results

Goal of this paper

- Explain the variation across time in credit risk
- Analyze the relationship between default risk and macroeconomic variables

Results to take away

- The paper provides a new structural model to price credit risk: it is simple and intuitive
- Theoretical relationships between the macro-variables provided by the model and predicted credit spreads are in line with the empirical literature
- The model generates credit spreads that explain the dynamics of EMBI+ spreads
  - Explain 92% of the time variation
- The structural model can be used to explore new debt contracts to lower the risk of defaulting and its repercussions on more general financial crises
Literature on Sovereign Credit Risk
Introduction

Theoretical literature

**Literature on sovereign lending:** *Explain the presence of sovereign debt*

  - Does not provide a clear understanding of why a sovereign defaults, or of when it defaults

**Literature on sovereign default:** *Structural models to explain default*

  - No formal international bankruptcy court
  - Debt renegotiation upon default
  - Exogenous foreign debt level

*These studies do not explain the time variation of sovereign credit spreads*
Introduction

Empirical literature

Literature on sovereign spreads: Credit spread fitting

- Reduced-form affine structure models
  - Duffie and Singleton (1999), Duffie, Pederson, and Singleton (2003), Longstaff, Pan, Pedersen, and Singleton (2007), and Pan and Singleton (2008)
- Reduced-form contingent-claims analysis
  - Weigel and Gemmill (2006), and Bodie, Gray, and Merton (2007)
- Panel-based approach
  - Hilscher and Nosbusch (2007) and the references therein

Predictions are based on historical data only: no structural decisions

Contribution of the paper

- Offer a structural model that explains the time variation in sovereign credit spreads
The Model
A classical first passage of time model à la Merton (1974)...
The model
Default and renegotiation in a snapshot

... except that the sovereign chooses a default policy and a level of debt to maximize the value of the economy
The revenues of the economy follow a stochastic process

\[ \text{Revenues} \]

\[ \text{Path of the revenues of the sovereign:} \]
\[ dx_t = \mu x_t dt + \sigma x_t dZ_t \]

\[ \text{Expected revenues path with drift } \mu \]

\[ T(x^N) \text{ Time} \]

\[ c^* \text{ Debt level} \]

\[ x_0 \]

\[ x^{N*} \text{ Endogenous default barrier} \]

\[ \text{Defaultable debt} \]
Default occurs when the revenues of the economy hit the default boundary

Expected revenues path with drift $\mu$

Path of the revenues of the sovereign:
\[ dx_t = \mu x_t dt + \sigma x_t dZ_t \]

Endogenous default barrier

Defaultable debt

Optimal stopping time
\[ T(x^{N^*}) = \inf \{ t \geq 0 \mid x_t \leq x^{N^*} \} \]
The model
Default and renegotiation in a snapshot

Upon default, the sovereign and its lenders renegotiate the terms of the debt contract
The model

Default and renegotiation in a snapshot

Each side benefits from the renegotiation round:

• Gain of the sovereign: avoid trade sanctions but must continue to partially service the debt
• Gain of the lenders: partially recover some value

Path of the revenues of the sovereign:
\[ dx_t = \mu x_t dt + \sigma x_t dZ_t \]

Expected revenues path with drift \( \mu \)

Endogenous default barrier

Optimal stopping time
\[ T(x^N) = \inf \{ t \geq 0 \mid x_t \leq x^N \} \]

Defaultable debt

Renegotiation on the debt reduction \( \phi^* \)
The model
Default and renegotiation in a snapshot

A Nash Bargaining game determines the debt reduction

Path of the revenues of the sovereign:
\[ dx_t = \mu x_t dt + \sigma x_t dZ_t \]

Expected revenues path with drift \( \mu \)

Endogenous default barrier

Optimal stopping time
\[ T(x^N) = \inf \{ t \geq 0 \mid x_t \leq x^N \} \]

Defaultable debt

Non-defaultable debt

Reduction of the debt coupon

Renegotiation on the debt reduction \( \phi^* \)

Debt level

Time

Revenues

Debt level

Default event
The model
Credit risk in a snapshot

The probability of defaulting determines the credit spread...

Revenues

| $x_0$ | $x^N$ | $x^-$ |

Distributions of the revenues at time $T$

Expected revenues path and actual path with drift $\mu$

Default barrier without renegotiation

Physical probability of defaulting

$T$  

Time
The model
Credit risk in a snapshot

... which needs to be computed under the risk-neutral probability measure.
The model
Credit risk in a snapshot

... which needs to be computed under the risk-neutral probability measure
The potential for renegotiating the terms of the debt contract increases the incentive to default.
The model
Credit risk in a snapshot

Distributions of the revenues at time T

Expected revenues with drift $r$

Risk-neutral probability of defaulting

New probability of defaulting

Default barrier with renegotiation

Default barrier without renegotiation

Probability of defaulting is higher if renegotiation is possible

... which raises credit risk
Theoretical Predictions of the Model
Results of the paper

Theoretical predictions

**Sovereign credit risk is high when**

- The economy grows slowly

- Macro-economic volatility is high

- Risk-free interest rates are high

- The sovereign is a large trading partner

- Domestic investment generates high returns
Empirical Results
Results of the paper

Daily predicted credit spreads versus EMBI+ spreads

- Use daily stock market indices to infer the best prediction on the state of the economy
  - Other parameters are constant (volatility, risk-free rate, ...)
- Generate spreads predicted by the model for Brazil, Mexico, Peru, and Russia over 1998-2006
  - FE Panel analysis in levels and in differences
    \[
    \ln(CS_{EMBI,i,t}) = \gamma_1 + \gamma_{2,i} \ln(CS_{Model,i,t-1}) + \omega_i + \tau_t + \nu_{i,t}
    \]
  - Explain 92% of the time variation in EMBI+ spreads with a single time-varying explanatory variable

Comparison

- Correlation between stock market indices and EMBI+ spreads: 40%
- Weigel & Gemmill (2006): $R^2 = 8\%$ with only stock market indices
- Hilscher & Nosbusch (2007): $R^2 = 48\%$ with 7 variables
- Bodie et al. (2007): $R^2 = 80\%$ using market prices
Results of the paper

Daily predicted credit spreads versus EMBI+ spreads

- Explain 92% of the time variation in daily EMBI+ spreads
  - Brazil, Mexico, Peru, and Russia, 1998-2006

[Note: EMBI+ spreads data and debt prices are not used as input!]

A. Jeanneret (Swiss Finance Institute - Harvard)
Empirics

Other explanatory factors: what about the VIX implied volatility index?

New regression:

$$\ln \left( CS_{EMBI,i,t} \right) = \gamma_1 + \gamma_2,i \ln \left( CS_{Model,i,t-1} \right) + \gamma_3 VIX_t + \gamma_4 UST_t + \omega_i + \tau_t + \nu_{i,t}$$

- The explanatory power rises only slightly, to 94%, when accounting for additional time-varying factors such as
  - 5-year U.S. Treasury rates
  - The VIX option-implied volatility index

- This finding may change one's interpretation of the results of Longstaff, Pan, Pedersen, and Singleton (2007) and Pan and Singleton (2008)

- These authors show that the VIX index is a key factor in explaining credit risk movements
  - They do not include the factors that I show to almost eliminate VIX as an additional explanatory variable
Conclusions
Conclusions

- Theoretical credit spread predictions of the model are in line with the empirical literature

- The model generates credit spreads that explain the dynamics of EMBI+ spreads

- A structural model can be used to explore new debt contracts to lower the risk of defaulting and its repercussions on more general financial crises

- The model can also be applied to investigate the
  - Link with exchange rate crises as most crises in emerging markets simultaneously involve an exchange rate and a default component
  - Link between default and banking crises
  - Optimal amount of reserves to hold in the balance sheet
  - Difference in credit risk between domestic and external debt