The climate-extended portfolio credit risk model

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The Climate-Extended Risk Model (CERM)

Iggaak UL Lusenn

A collaboration built on strong convictions :

We recognize the investments the OECD has identified to successfully achieve Net Zero Emissions by 2050 **require banks** to accelerate the green transition.

We are committed to this goal by working with financial institutions to **optimise their climate risk capital budget**.

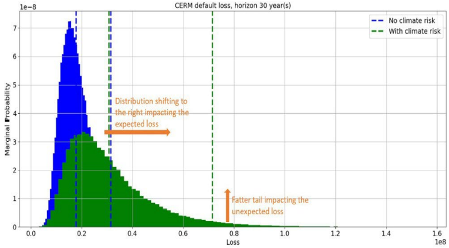
We believe rigorous analysis and **open collaboration** as well as employing open financial modelling can help institutions meet this goal.

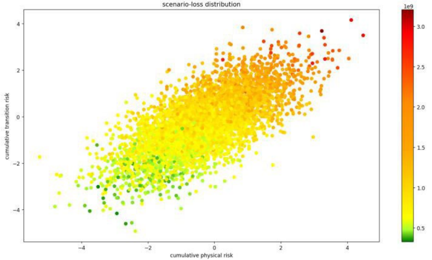
The history:

- July 2020: publication by Green RWA of '**How bank can save the planet**' at the origin of the model.
- December 2020: publication of the **CERM** mathematically formalized by Josselin Garnier.
- 2021: **Numerical application and integration** with atoti by Iggaak. Presentation of the model by Green RWA to major institutions: **FED, ECB, IMF, European commission, UNEP FI**.
- 2022: publication by Green RWA of the '**Stochastic Climate Model**' as a practical calibration method of the CERM. Presentations to commercial banks by Iggaak and ActiveViam (atoti).

The objectives of the model

- Compute **climate-extended metrics** for climate reporting/disclosure
- Assess **sustainability** of **net-zero transition scenarios** of lending portfolios under non stationary climate risk factors
- Provide pricing tools to capture **profitable financing opportunities** of **transition projects**
- **Optimization** of banks' climate strategy





Loss for a credit portfolio

- Goal: assess the loss of a credit portfolio taking into account economic and climate (physical and transition) risks.
- The loss of the portfolio L is the sum of the random losses of the borrowers.
- The expected loss $L^{\mathrm{e}} = \mathbb{E}[L]$ of the portfolio
  - is the sum of the expected individual losses,
  - can be expressed by grouping the borrowers:

  The borrowers belong to different groups $g = 1, \dots, G$, that represent
  - geographic regions,
  - economic sectors,
  - climate risk mitigation and adaptation strategies,
  - collateral types.

  The borrowers have different ratings $i = 1, \dots, K-1$ at time 0 (the rating K is default).

Expected loss of the portfolio

Expected loss L^{e} at the time horizon T:

$$L^{\mathrm{e}} = \sum_{t=1}^{T} L_t^{\mathrm{e}},$$

$$L_1^{\mathrm{e}} = \sum_{g=1}^{G} \sum_{i=1}^{K-1} (\boldsymbol{M}_{g,1})_{iK} \mathrm{LGD}_{g,i,1} \mathrm{EAD}_{g,i,1},$$

$$L_t^{\mathrm{e}} = \sum_{g=1}^{G} \sum_{i,j=1}^{K-1} \big(\boldsymbol{M}_{g,1} \cdots \boldsymbol{M}_{g,t-1}\big)_{ij} (\boldsymbol{M}_{g,t})_{jK} \mathrm{LGD}_{g,j,t} \mathrm{EAD}_{g,i,t}, \text{ for } t \geq 2.$$

Here

- $\boldsymbol{M}_{g,t}$: unconditional $K \times K$ migration matrix,
- $\mathrm{EAD}_{g,i,t}$: Exposition At Default, total exposure at default (in case of default at time t) for all borrowers in group g and with initial rating i,
- $\mathrm{LGD}_{g,j,t}$: Loss Given Default,

depend on the group $g \in \{1, \dots, G\}$ and time $t \in \{1, \dots, T\}$.

Unexpected loss of the portfolio

- The expected loss $L^{\mathrm{e}} = \mathbb{E}[L]$ of the portfolio is the sum of the expected individual losses.
- The unexpected loss is a quantile L^{u} of the loss of the portfolio:

$$\mathbb{P}(L \leq L^{\mathrm{u}}) = 0.999 \text{ (or } 0.99 \text{ or } 0.9)$$

The quantile of a sum is not the sum of the quantiles.
$\hookrightarrow$ A model is needed for the dependence structure.

Asymptotic Single Risk Factor (ASRF) model

The ASRF model

- is a default-mode (Merton-type) model proposed by Vasicek in 1991,
- has played a central role for its regulatory applications in the Basel Capital Accord Framework,
- is based on the following assumptions:

1. a unique systematic risk factor (single-factor model): economic risk
$\hookrightarrow$ the losses of the borrowers are correlated only through one systematic factor,
2. an infinitely granular portfolio (characterized by a large number of small size loans)
$\hookrightarrow$ diversification of the idiosyncratic risks, but not of the systematic risk,
3. a dependence structure described by a Gaussian copula
$\hookrightarrow$ the most important theoretical hypothesis,

- gives closed-form expressions for the expected and unexpected losses.

Asymptotic Single Risk Factor (ASRF) model

- The qth borrower defaults before time t if a latent variable $X_t^{(q)}$ (normalized asset) goes below a threshold value:

$$X_t^{(q)} = a^{(q)} Z_t + \sqrt{1-(a^{(q)})^2}\,\varepsilon_t^{(q)}$$

  where
  - $Z_t =$ systematic (economic) risk factor,
  - $\varepsilon_t^{(q)} =$ idiosyncratic factor,
  - $a^{(q)} = a_g$ factor loading (Basel: constant; here: depends on group).

  Gaussian copula: $(Z_t, \varepsilon_t^{(1)}, \varepsilon_t^{(2)}, \dots)$ are i.i.d. standard Gaussian.
- The threshold values are obtained from the group-dependent unconditional migration matrices

$$z_{g,ij} = \Phi^{-1}\Big(\sum_{j'=j}^{K} (\mathbf{M}_g)_{ij'}\Big), \qquad \mathbb{P}\big(X_t^{(q)} \leq z_{g,ij}\big) = \Phi(z_{g,ij})$$

- The group-dependent conditional migration matrix is

$$\sum_{j'=j}^{K} (\mathbf{M}_g(Z_t))_{ij'} = \mathbb{P}\big(X_t^{(q)} \leq z_{g,ij} | Z_t\big) = \Phi\Big(\frac{z_{g,ij} - a_g Z_t}{\sqrt{1-(a_g)^2}}\Big)$$

Climate-Extended Risk Model (CERM) - principle

The Climate-extended model

- is a Multi-Factor Merton-type model,
- is based on the following assumptions:

1. several systematic risk factors (multi-factor model): economic, physical, transition risks,
2. an infinitely granular portfolio (characterized by a large number of small size loans),
3. a dependence structure described by a Gaussian copula,

- gives efficient Monte-Carlo estimations of the expected and unexpected losses.

Basic references:

- Vasicek Model
  Vasicek, O., The distribution of loan portfolio value, Risk, Dec. 2002.
- Multi-Factor Merton Model
  Pykhtin, M., Multi-factor adjustment, Risk, March 2004.

Climate-Extended Risk Model (CERM) - ingredients

Additional ingredients (compared to ASRF):

- Idiosyncratic risks, economic risk are stationary.
- Physical and transition risks evolve in time.
  Physical risk factors can be regional.
  $\hookrightarrow$ *Climate scenarios are needed for the intensities of the systematic risk factors.*
- Systematic risk factors can be correlated.
  For instance, anti-correlation between economic and transition risks or correlation between regional physical risks.
  $\hookrightarrow$ *Correlation structure between systematic risk factors is needed.*
- Expositions of borrowers to systematic risk factors (micro-correlations) may evolve in time (mitigation strategies).
  $\hookrightarrow$ *Micro-correlations w.r.t. all systematic risk factors are needed for all groups.*
- The historical unconditional migration matrices are used at $t = 0$.
  $\hookrightarrow$ *Same historical migration matrices as for ASRF model are needed.*

Climate-Extended Risk Model (CERM) - structure

The qth borrower defaults before time t if a latent variable $X_t^{(q)}$ (normalized asset) goes below a threshold value:

$$X_t^{(q)} = \boldsymbol{a}_t^{(q)} \cdot \boldsymbol{Z}_t + \sqrt{1 - \boldsymbol{a}_t^{(q)} \cdot \mathbf{C}\boldsymbol{a}_t^{(q)}}\,\varepsilon_t^{(q)}$$

where

$\boldsymbol{Z}_t$ = systematic risk factors (with correlation matrix $\mathbf{C}$),

$\varepsilon_t^{(q)}$ = idiosyncratic factor,

$\boldsymbol{a}_t^{(q)}$ = factor loadings; they are the products of time-dependent macro-correlations and time- and group-dependent micro-correlations.

- macro-correlations: intensities of the systematic risk factors, expressed in same units (impact to GDP growth rate for instance);
  - *constant* for economic risk;
  - given by *(IPCC) carbon emission pathway* for transition risk;
  - given by *(IPCC) GDP growth rate assessment* for physical risk.
- micro-correlations: expositions of borrowers to systematic risk factors;
  - given by *climate ratings*.

Climate-Extended Risk Model (CERM) - results

Conditional loss given the systematic risk factors $\boldsymbol{Z} = (\boldsymbol{Z}_1, \ldots, \boldsymbol{Z}_T)$:

$$L(\boldsymbol{Z}) = \sum_{t=1}^{T} L_t(\boldsymbol{Z})$$

$$L_1(\boldsymbol{Z}) = \sum_{g=1}^{G} \sum_{i=1}^{K-1} (\boldsymbol{M}_{g,1}(\boldsymbol{Z}_1))_{iK} \mathrm{LGD}_{g,i,1}(\boldsymbol{Z}_1) \mathrm{EAD}_{g,i,1}$$

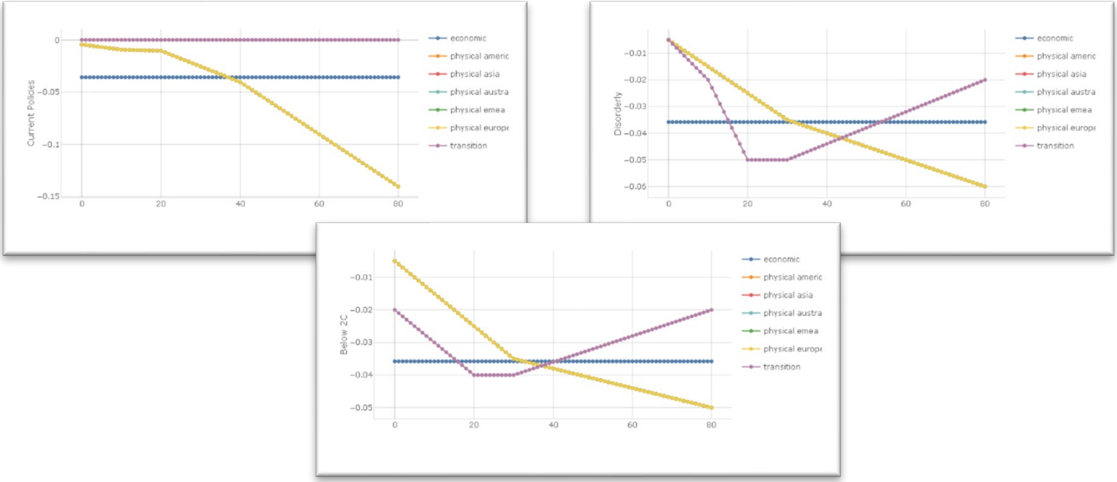
$$L_t(\boldsymbol{Z}) = \sum_{g=1}^{G} \sum_{i,j=1}^{K-1} \big(\boldsymbol{M}_{g,1}(\boldsymbol{Z}_1) \cdots \boldsymbol{M}_{g,t-1}(\boldsymbol{Z}_{t-1})\big)_{ij} (\boldsymbol{M}_{g,t}(\boldsymbol{Z}_t))_{jK} \mathrm{LGD}_{g,j,t}(\boldsymbol{Z}_t) \mathrm{EAD}_{g,i,t}$$

for $t \geq 2$. Here

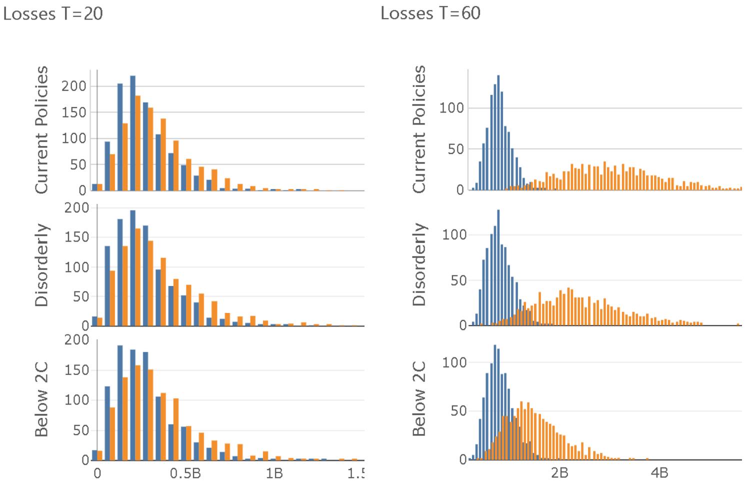
- Explicit formulas are available for all terms.
- $L^{\mathrm{e}} = \mathbb{E}[L(\boldsymbol{Z})]$.
- L^{u} such that $\mathbb{P}(L(\boldsymbol{Z}) \leq L^{\mathrm{u}}) = 99.9\%$ (or 99% or 90%).
- Monte Carlo simulations can be carried out to estimate L^{u} or the distribution of $L(\boldsymbol{Z})$.
- Sensitivity indices (w.r.t. groups) can be estimated.

Climate Scenarios Example (Macro-correlations) [IEA, NGFS, Internal]

Example of macro-correlation parameters from 2020 to 2100 for three NGFS scenarios: Current Policies (left), Disorderly (right), and Below 2°C (bottom). The blue lines stand for the economic risk intensity, the magenta lines stand for the transition risk intensity, and the yellow lines stand for the physical risks' intensity (all physical risks share the same intensity).



Loss Distributions



Loss distributions with the CERM-based approach on the pilot portfolio and on the three NGFS climate scenarios: Current Policies (top), Disorderly (center), and Below 2°C (bottom).

In the left column the horizon is 2042, in the right column it is 2082. The blue distributions are obtained with only economic risk, in absence of transition and physical risks, and are, therefore, identical for the three scenarios (up to Monte Carlo fluctuations).

The orange distributions are obtained in presence of economic, transition and physical risks.

Climate-Extended Risk Model (CERM) - summary

- Objectives:
  - Determine the loss distribution of a a credit portfolio.
  - Propose a credit risk model which extends the model defined by the Basel Committee to climate (physical and transition) risks.
- Ingredients:
  - Credit/climate rating, (IPCC) scenarios.
  - Initial loan distribution, reloading of outstanding loans.
- Results:
  - Measure the incremental cost of risk and capital to inform credit allocation decisions.
  - Optimize the overall climate strategy, including financing existing clients' adaptation/mitigation plans and shifting assets to green lenders and green collateral.