The P2P pandemic swap: decentralized pandemic-linked securities

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- Pandemic risk is systematic
  - Strong positive dependence.
  - Diversification of pandemic risks is difficult.
- Heterogeneous risks:
  - When and how much extra capital is needed depends on the country.
- Size of the pandemic losses
  - exceeds the capacity of the insurance market;

- We introduce the class of

P2P Pandemic-linked securities.

- Transfer part of the risk to the financial market:
  - similar to CAT bonds, longevity bonds, CDOs, etc.
- Use a peer-to-peer network between countries.
  - mutual support between countries.
  - Abdikerimova & Feng (2022) and Denuit, Dhaene & Robert (2022).

Cashflows in case of a pandemic event

- The countries are organised in a P2P network
  - In case a payment is triggered for country j, each country pays a share of the benefit amount s_j:

$$\alpha_{ij} \times s_j = \text{Payment of country } i \text{ to country } j.$$

- Pandemic swap:
  - Insurance for the losses which are not covered by the pool.

$$\alpha_{0j} \times s_j = \text{Amount the investors pay to country } j\ .$$

The investors

- Premium Income:
  - Payment dates:
  $$0 < t_1 < \ldots < t_N = T.$$
  - The pool of countries collectively fund the premiums:
  $$cF\Delta_t = \text{Premium paid at each payment date}$$
- Benefit payments:
  - Premium payments stop when the **first loss** is triggered.
  - The maximal amount paid by the investors during the lifetime of the swap is equal to F.

Conditions for the payments

- **Conservation of zero balance for risk sharing**

$$\sum_{i=0, i \neq j}^{n} \alpha_{ij} = 1, \quad \text{for } j = 1, 2, \ldots, n. \tag{1}$$

  - The contributions of the investors and countries are sufficient to cover country j.

- **Collective payment of premiums**

$$\sum_{i=1}^{n} \alpha_{i0} = 1. \tag{2}$$

  - The aggregate contributions of the countries are sufficient to cover the premium.

Conditions for the payments

- **Principle of indemnity**

$$0 \leq \alpha_{ij} \leq 1, \quad i,j \geq 0. \tag{3}$$

- **Maximum principal loss.**

$$\sum_{j=1}^{n} s_j \alpha_{0j} = F. \tag{4}$$

  - In the most extreme event where all countries will be triggered, the full amount F will be used.

The expected return for the countries and the investors

- The cashflow of country i at time t_j:

$$R_i(t_j) = s_i I_i(t_j) - \alpha_{i0} F c \Delta t I_0(t_j) - \sum_{k=1, k\neq i}^{n} \alpha_{ik} s_k I_k(t_j).$$

  - The benefit payment in case of a triggering pandemic event.
  - The premium payment in case no payment was yet triggered.
  - P2P payments to other countries.

- The time-0 return for country i:

$$R_i = \sum_{j=1}^{N} \mathrm{e}^{-rt_j} R_i(t_j),$$

where r is the risk-free rate which is assumed to be deterministic and constant.

The expected present value for the countries and the investors

- Expected present value of the cash flows for country i:

$$\mathbb{E}[R_i] = s_i q_i - \alpha_{i0} (Fc\Delta t) p_0 - \sum_{k=1, k\neq i}^{n} \alpha_{ik} s_k q_k.$$

- Fairness of a P2P pandemic swap:
  - The P2P pandemic swap is **fair** if the expected present value for each country is zero:

$$\mathbb{E}[R_i] = 0, \text{ for } i = 1, 2, \ldots, n.$$

Fairness

- Result:
  - If the P2P bond is fair, we have that $\mathbb{E}[R_0] = 0$.
- Relation between q_i, p_0 and c:

$$cF\Delta_t \times p_0 = \sum_{k=1}^{n} s_k \alpha_{0k} \times q_k.$$

An intensity model: the marginal probabilities

- The time that the payment for country i is triggered is τ_i.
- Denote the intensity for country i by λ_i:

$$\mathbb{P}\left[\tau_i > t\right] = \mathrm{e}^{-\lambda_i t}.$$

- Then:

$$q_i = \frac{\left(1 - \mathrm{e}^{-\lambda_i \Delta t}\right) \mathrm{e}^{-(\lambda_i + r)\Delta t} \left(1 - \mathrm{e}^{-(\lambda_i + r)T}\right)}{1 - \mathrm{e}^{-(\lambda_i + r)\Delta t}}.$$

- In order to model the **premium payments**, we need the **dependence** structure between the random variables τ_i.

An intensity model: dependence

- Ordered probabilities:

$$e^{-\lambda_1} \geq e^{-\lambda_2} \ldots \geq e^{-\lambda_n}.$$

  - Country 1 is the safest country. Country n is the riskiest.

- We assume:

$$\mathbb{P}\left[\tau_{i+1} \leq t \middle| \tau_i \leq t\right] = 1, \text{ for } i = 1, 2, \ldots, n-1.$$

  - If a payment for country i was triggered before t, all riskier countries also received their benefit payment before time t.

An intensity model: dependence

- Triggers are ordered:
  - The first country to receive a benefit payment is the riskiest country, followed by the 2nd riskiest country, etc.
  - See also Dhaene & Goovaerts (1997).
- Premium payments:

$$\mathbb{E}\left[I_0\right] = p_0 = \frac{\mathrm{e}^{-(\lambda_n + r)\Delta t}\left(1 - \mathrm{e}^{-(\lambda_n + r)T}\right)}{\left(1 - \mathrm{e}^{-(\lambda_n + r)\Delta t}\right)}.$$

  - The expectation only depends on the intensity of the riskiest country.

The single-trigger case

- Assume a single trigger:
  - The probability and moment of triggering a pandemic loss payment is the same for each country.
- Coupon:

$$c = \frac{q}{\Delta_t p_0} \approx \lambda.$$

  - λ : the intensity of the single trigger.
  - The P2P pandemic swap behaves as a defaultable bond with zero recovery; see e.g. De Spiegeleer & Schoutens (2019).

Two country case

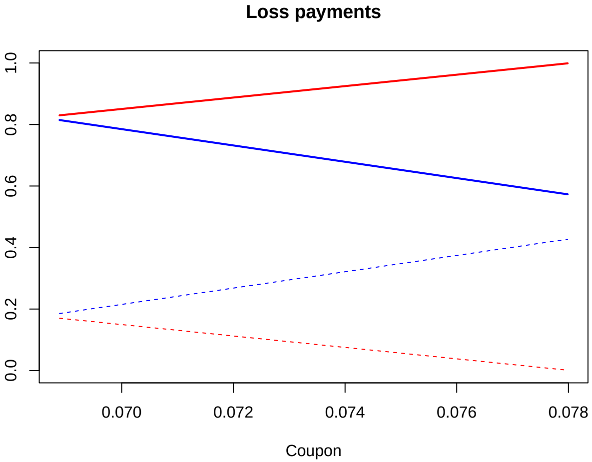

Figure. Solid lines: payments of the investors to country 1 (blue) and country 2 (red). Dashed lines are the payments between countries.

Two country case

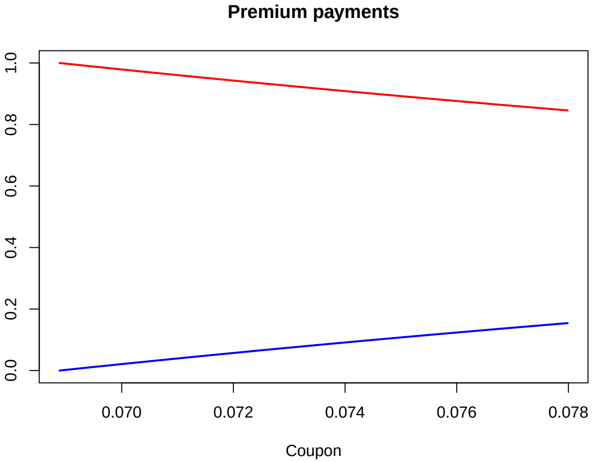

Figure. The proportion of the premium payment paid by country 1 (blue) and country 2 (red).

Thank you for your attention!

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