A causal machine learning approach for estimating heterogeneous treatment effects in the primary catastrophe bond market

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Outline

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Introduction

Market timing

- Broad concept in finance
- Here: Strategic issuance of securities at specific times
- Goal: A financially favourable outcome
- Importance: Impact on cost of capital and offering success

Strands of market timing literature

1. Traditional financial markets
    - Highly regulated
    - Standardised investment products
    - Transparent pricing mechanisms
    - Broad investors' participation
    - Focus on equity and dept capital markets

Strands of market timing literature

2. Alternative markets

   - Less regulatory scrutiny
   - Less standardised products
   - More opaque pricing mechanisms
   - Smaller investor base
   - Focus on hedge funds and venture capital

Gap: What about other alternative asset classes?

Catastrophe bonds

What are they?

- Financial instrument
- Payment contingent on a catastrophe risk

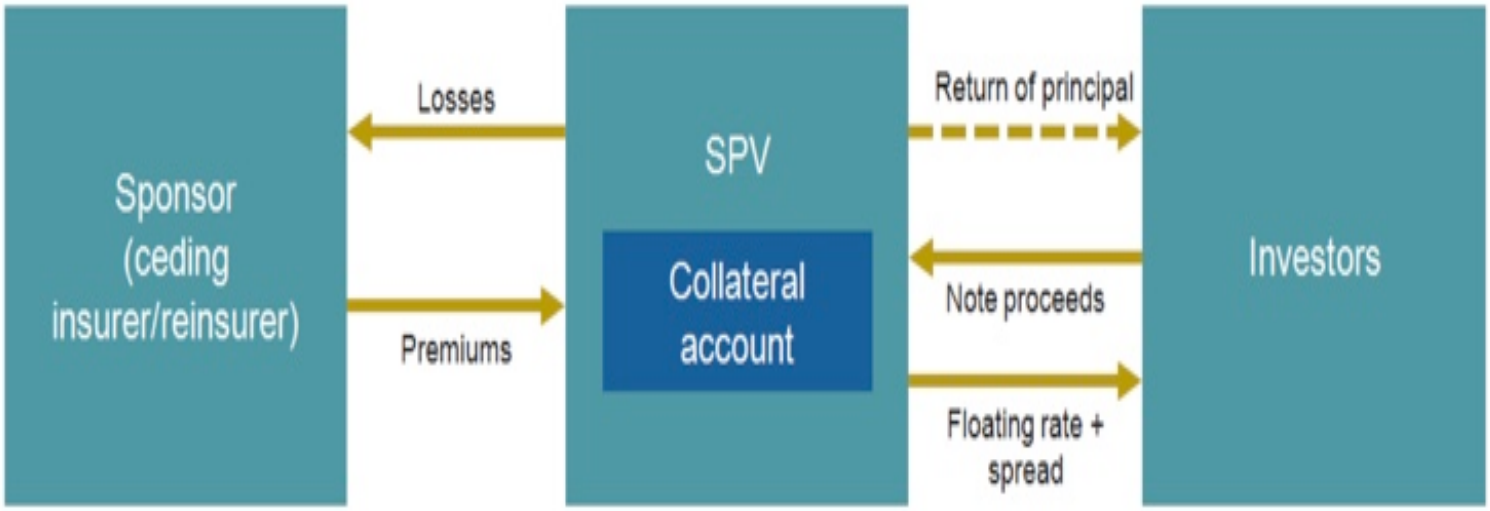
What they are used for?

- Extra catastrophe risk bearing capacity
- Diversification and high investment returns

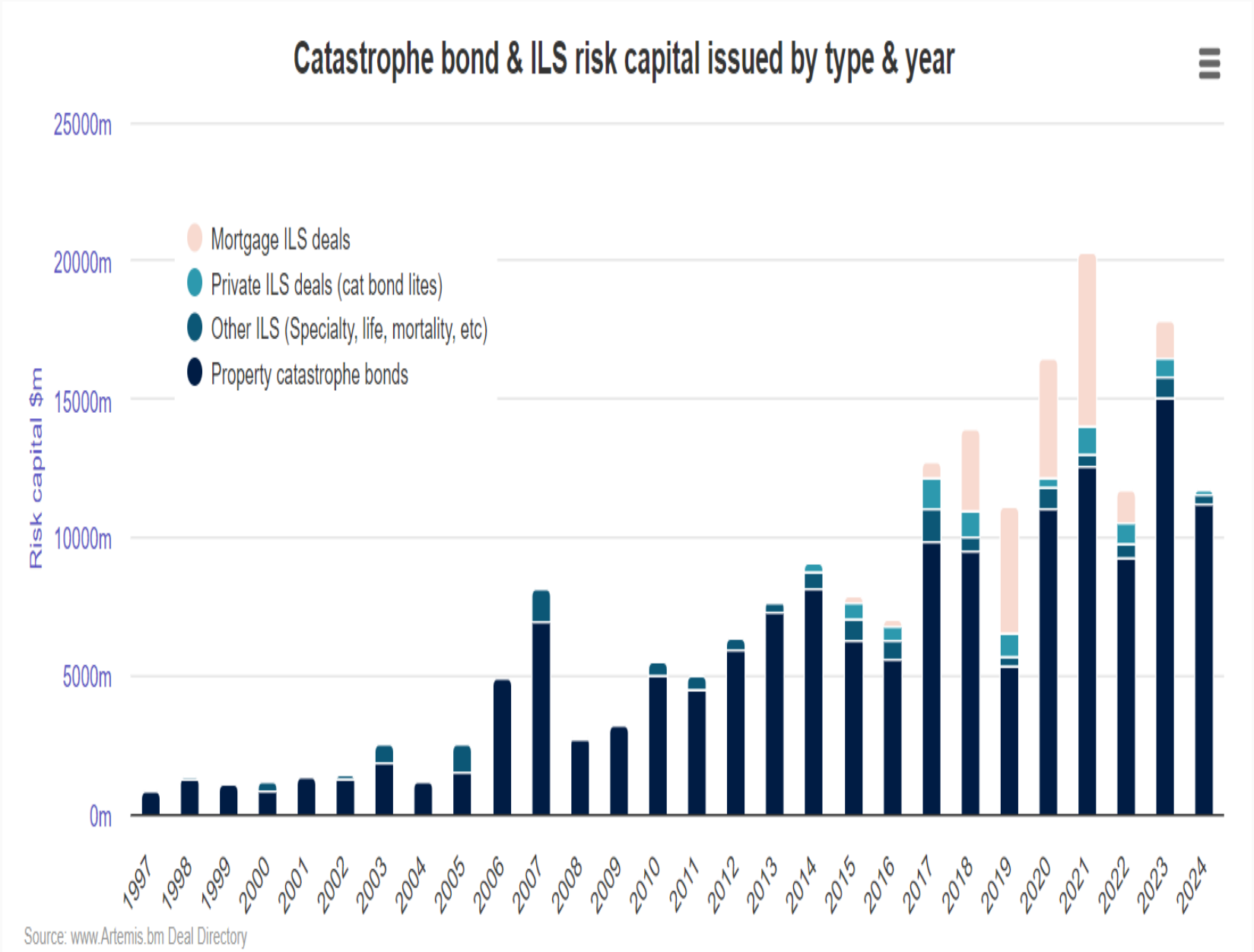
Other facts

- Over the counter market
- Size of $\approx$ USD 45 billion

Catastrophe bond structure



Catastrophe bond issuance over time



Why market timing for catastrophe bonds?

- Rapidly growing asset class
- Impact on the cost of catastrophe risk transfer for the issuer
- Seize attractive entry points for the investor
- Catastrophe bonds are ”bespoke” to customise sponsors needs
  $\rightarrow$ different subgroups might react differently to various issuance times

Our contribution

Our contribution

- Alternative capital market timing $\rightarrow$ Catastrophe bonds
- Non-parametric estimation of the causal effect of catastrophe bond issuance timing on their spreads
- Causal effect may vary for different catastrophe bond subgroups
- Find the drivers of the estimated causal effect heterogeneity

Catastrophe bond data

Catastrophe bond data

- Time period: Dec 2009 to May 2008 (934 obs.)
- Response: spread at issuance
- Treatment: issuance in the first half of calendar year
- Predictors (12 in total): catastrophe bond characteristics and macroeconomic factors

Methodology

Method highlights

- Causal forest - Athey et al. (2019)
- Extension of classic random forest of Breiman (2001) for heterogeneous treatment effect estimation
- Difference on how the quality of a split is determined in the tree development process
  a. Classic random forest $\rightarrow$ minimise the prediction error
  b. Causal forest $\rightarrow$ maximise the heterogeneity in the quantity of interest across the tree's child nodes

Setting

- Training data which consist of tuples $Z_i = (X_i, Y_i, W_i)$ for $i = 1, ..., n$
- $X_i = \{X_{1n}, X_{2n}, ...X_{nP}\}$ is a feature vector indexed by dimension $p = 1, 2, ..., P$ and it is an element of $\mathbb{R}^p$
- $Y_i \in \mathbb{R}$ is the response
- $W_i \in \{0, 1\}$ is the treatment assignment
- We aim to estimate the heterogeneous conditional average treatment effect $\tau(x) = \mathbb{E}[Y_i^{(1)} - Y_i^{(0)} | X_i = x]$ at a pre-specified test point x

Causal forest

- We build a causal forest *CF*, as shown in 1, by averaging estimates τ obtained by training honest causal trees Γ over random sub-samples $\mathcal{I} \in \{i = 1, ..., n\}$ of size $|\mathcal{I}| = s$ whilst $\xi \sim \Xi$ is a source of auxiliary randomness

$$CF(x; Z_1, ..., Z_n) = \binom{n}{s}^{-1} \sum_{1 \leq i_1, i_2, ..., i_s \leq n} \mathbb{E}_{\xi \sim \Xi}[\Gamma(x; Z_1, ..., Z_n)] \tag{1}$$

- Variable importance: A simple weighted sum of how many times feature X_i was split on at each depth in the forest *CF*

Results

Histogram of CF predictions

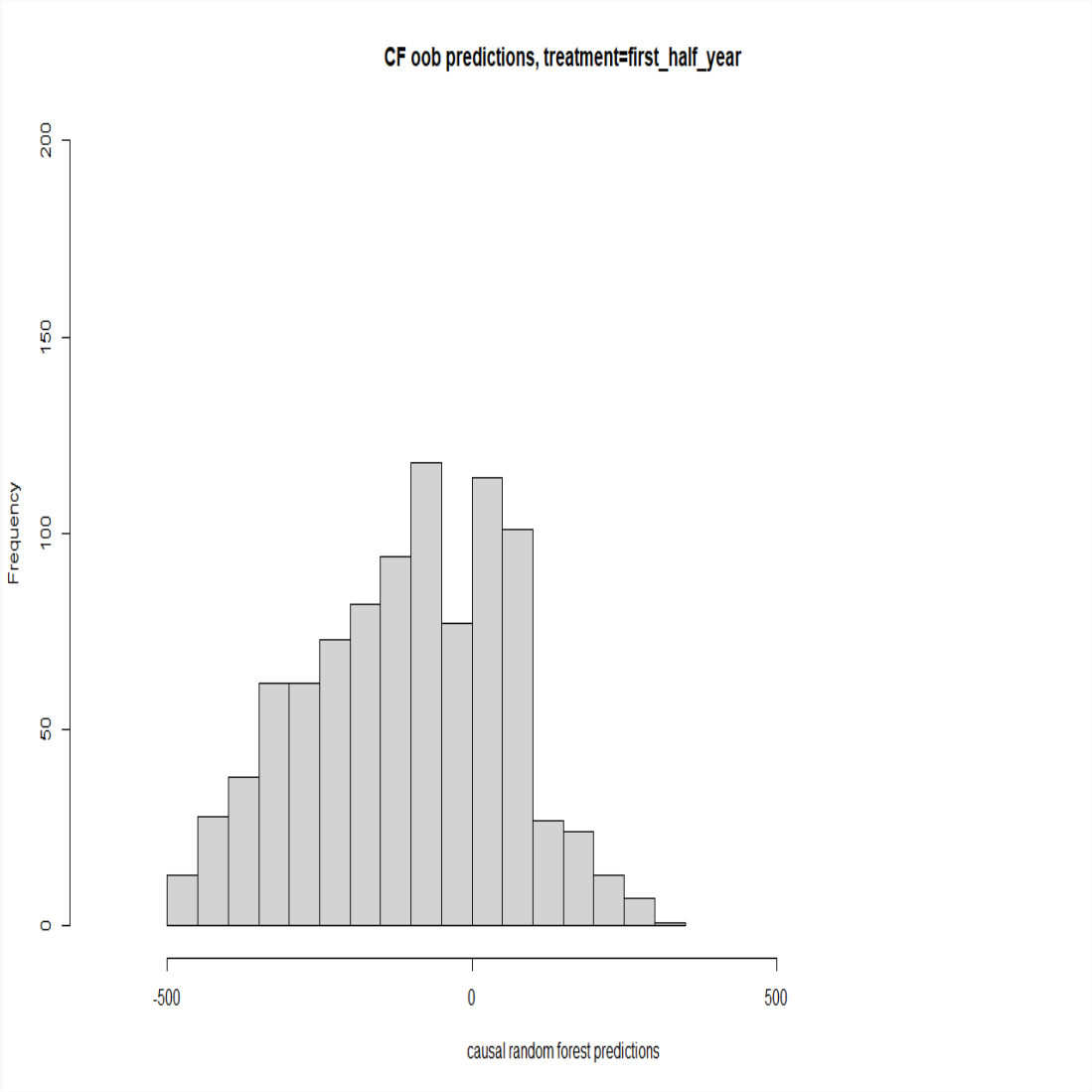


Figure 1: Frequency versus different ranges of the estimated differences in spreads for cat bonds issued in the first part of the year against the counter-fact.

Variable importance

Variable	Importance
size	0.215
ROL	0.198
AP	0.184
EL	0.140
term	0.100
BBSPR	0.047
loc peril	0.040
rating	0.029
peak	0.021
trigger	0.010
coverage	0.007
SR	0.006
vendor	0.003
Total	1.0000

Table 1: Weighted sum of how many times a feature was split on at each depth in the forest.

Key takeaways

Key takeaways

- Market timing in the primary catastrophe bond market
- Heterogeneous effect of issuance timing on catastrophe bond spreads
- On average, issuing in the first half of the year is ”cheaper” for the issuer
- Main drivers of heterogeneity: size of catastrophe bonds coverage and market conditions

Thank you!