Insurance
Data
Science

Pricing Workers' Compensation via Bayesian Hierarchical Modeling

Insurance Data Science Conference

20th of June 2025

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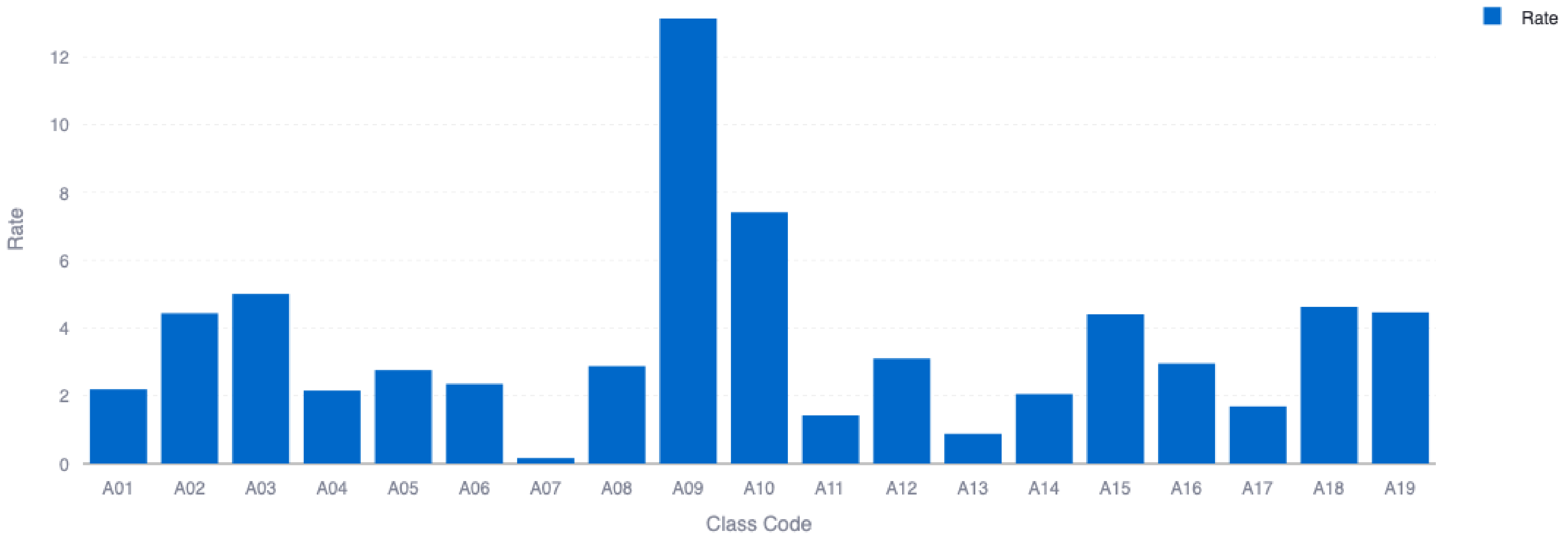
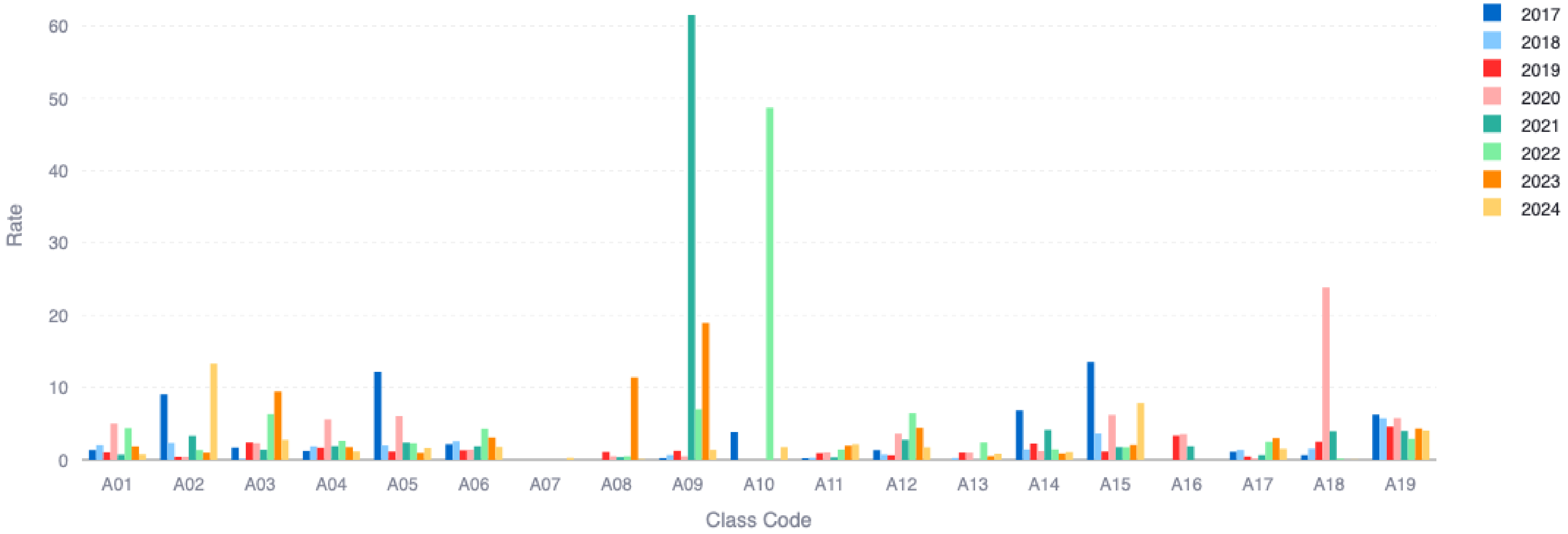
Context

- Exposure data is **highly heterogeneous**, and losses are **heavy-tailed**.
- The goal is to **improve accuracy** over Bühlmann-Straub estimators and to obtain a **probabilistic representation** of the rates.
- Bayesian hierarchical modeling is a **natural framework** for improving credibility estimators.

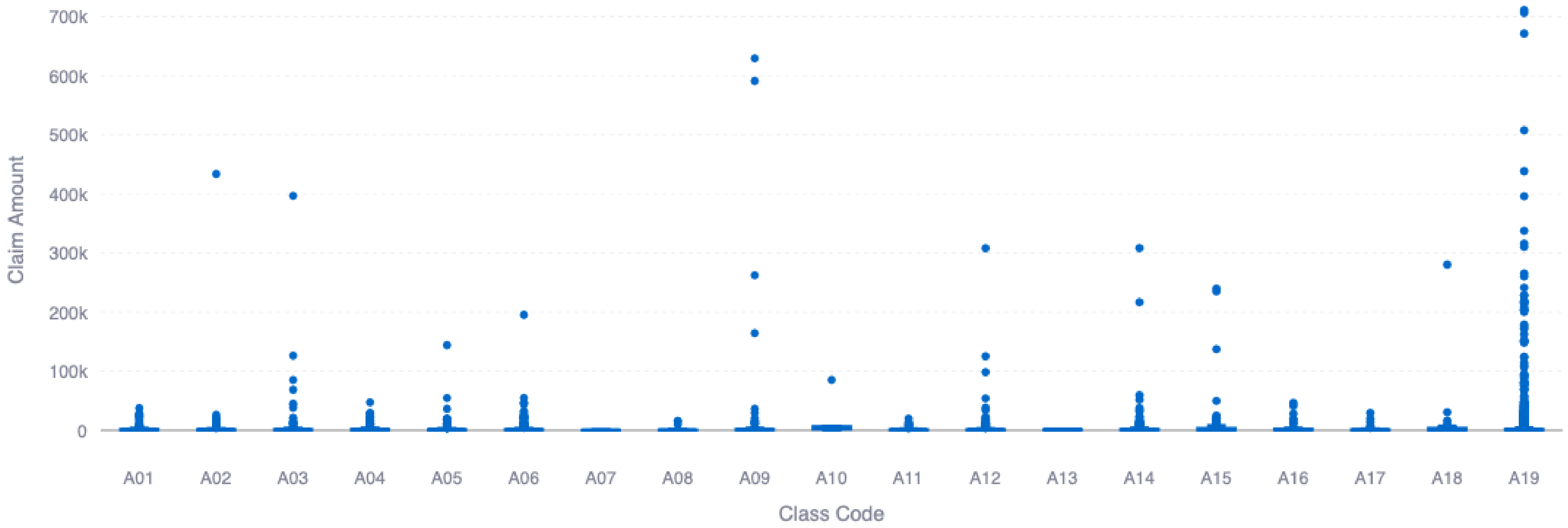
The problem: class-specific rate estimation



Variance can be decomposed into *within* and *among* classes



A portion of *within-class* variance comes from individual loss variation



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The starting point: Normal-Normal Hierarchical Model

- Starting with a simple model for the pure rate random process

$$r_{ji} \sim N\left(r_j, \frac{\sigma}{\sqrt{e_j}}\right)$$

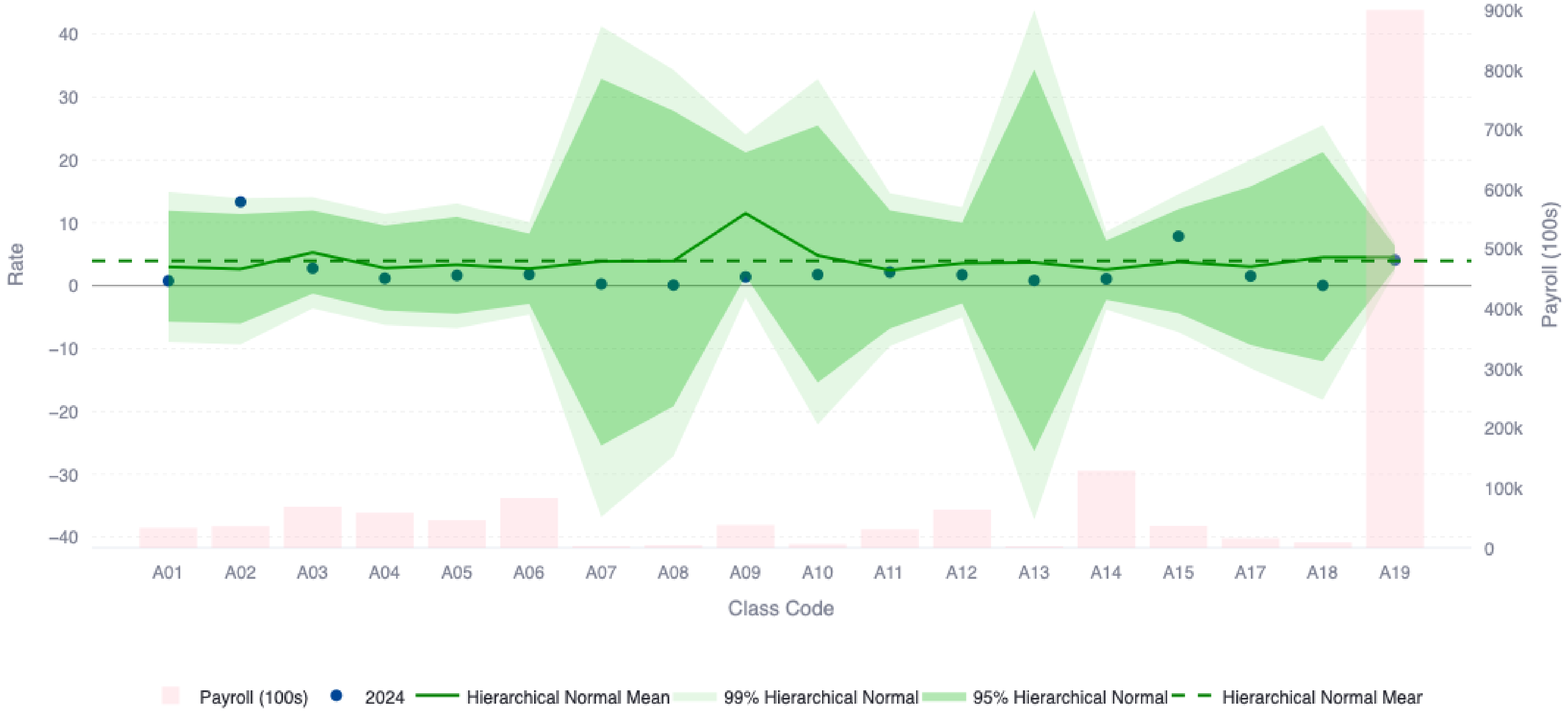
$$r_j \sim N(r_0, \tau)$$

where r_{ji} is the rate for class j in year i, centered at the class-mean r_j, e_j are class exposures, and r_0 the collective mean.

- σ^2 and τ^2 represent the **variance within and between** classes, respectively.

- For known variance parameters, the posterior mean is **"credibility-exact".**

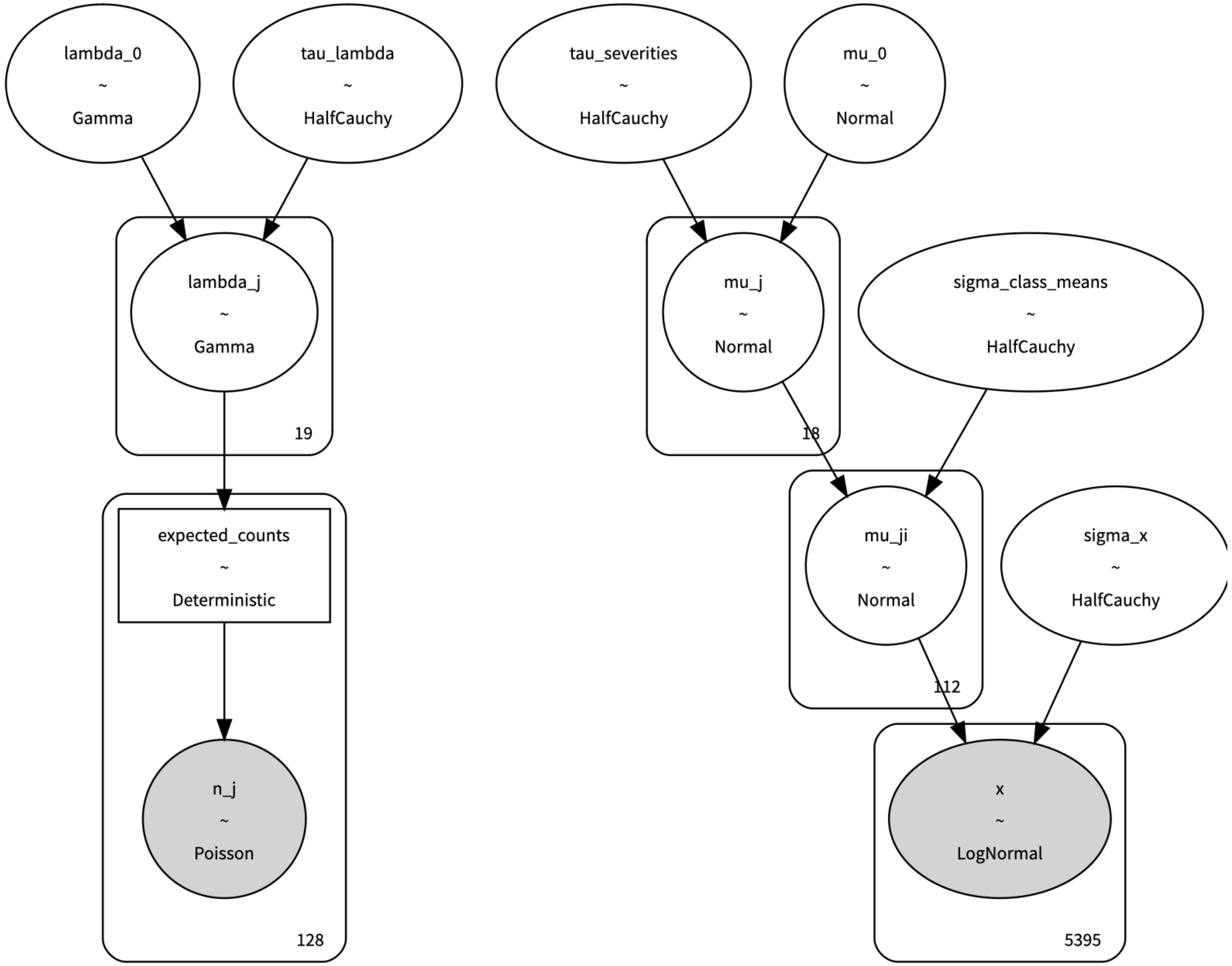
Poor shrinkage and wide predictive posterior on the validation set



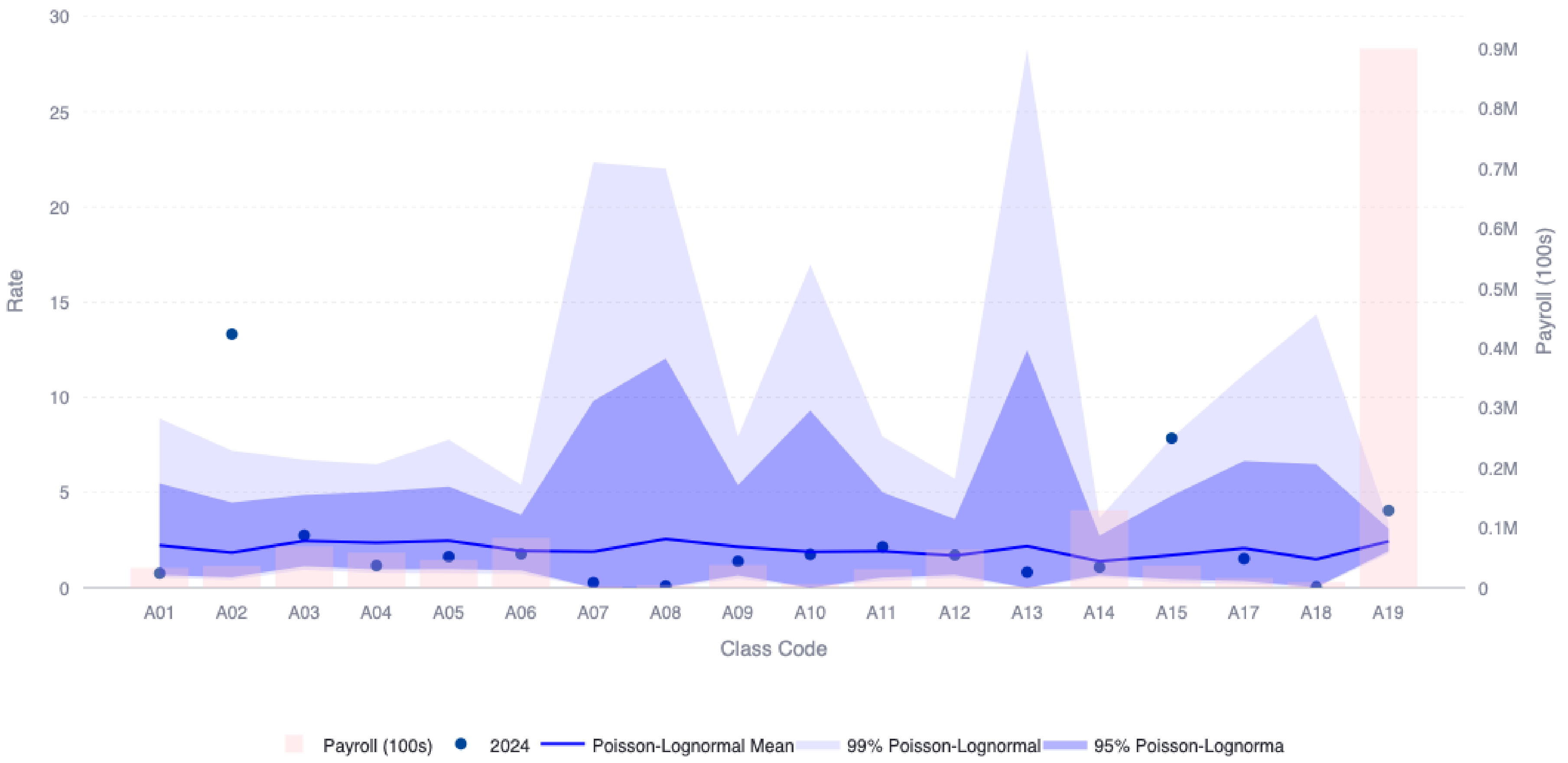
Shortfalls

- No distributional assumptions at individual loss level.
- There is “left skewness” at rate (aggregate loss) level.
    - These lead to **inaccurate credibility-weighting** (low shrinkage for most classes).

Lognormal/Poisson BHM: A simple model improvement



Reasonable skewed predictive distributions



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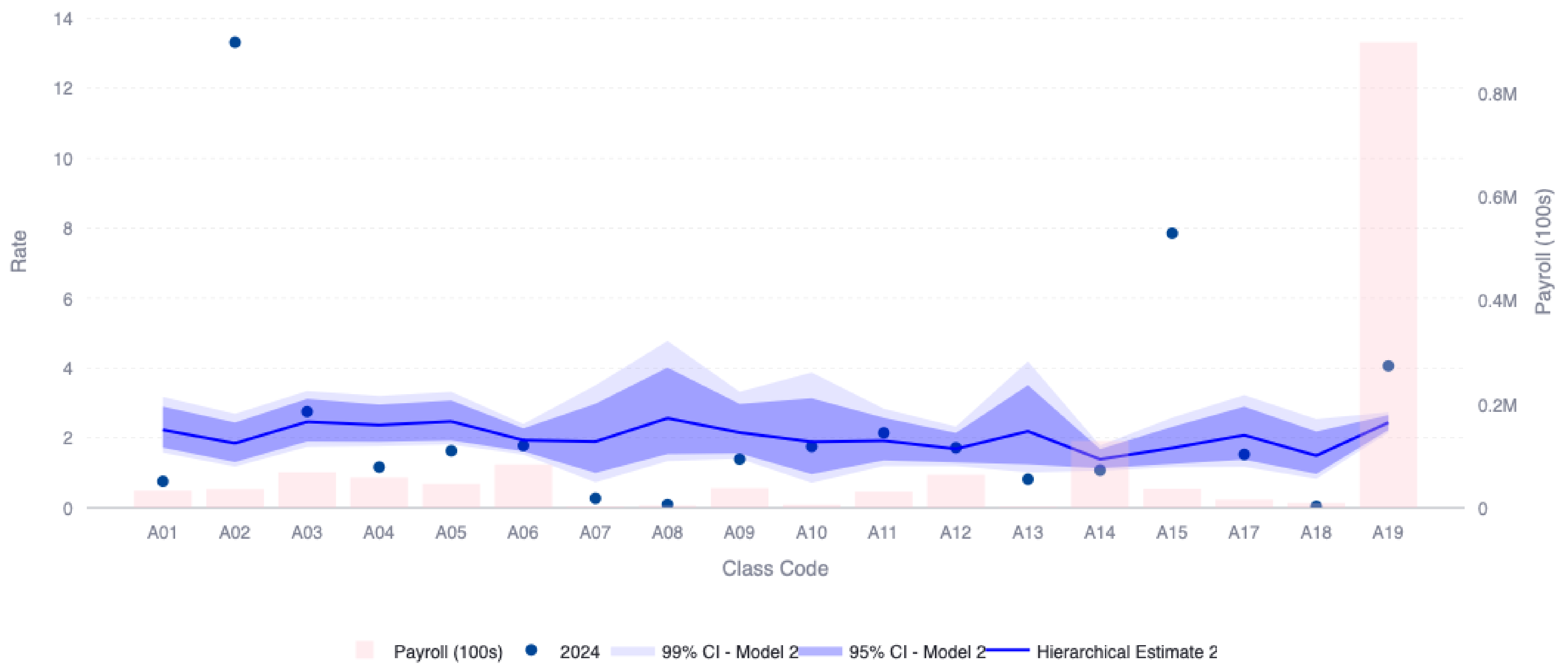
Lower mean variation produces more shrinkage



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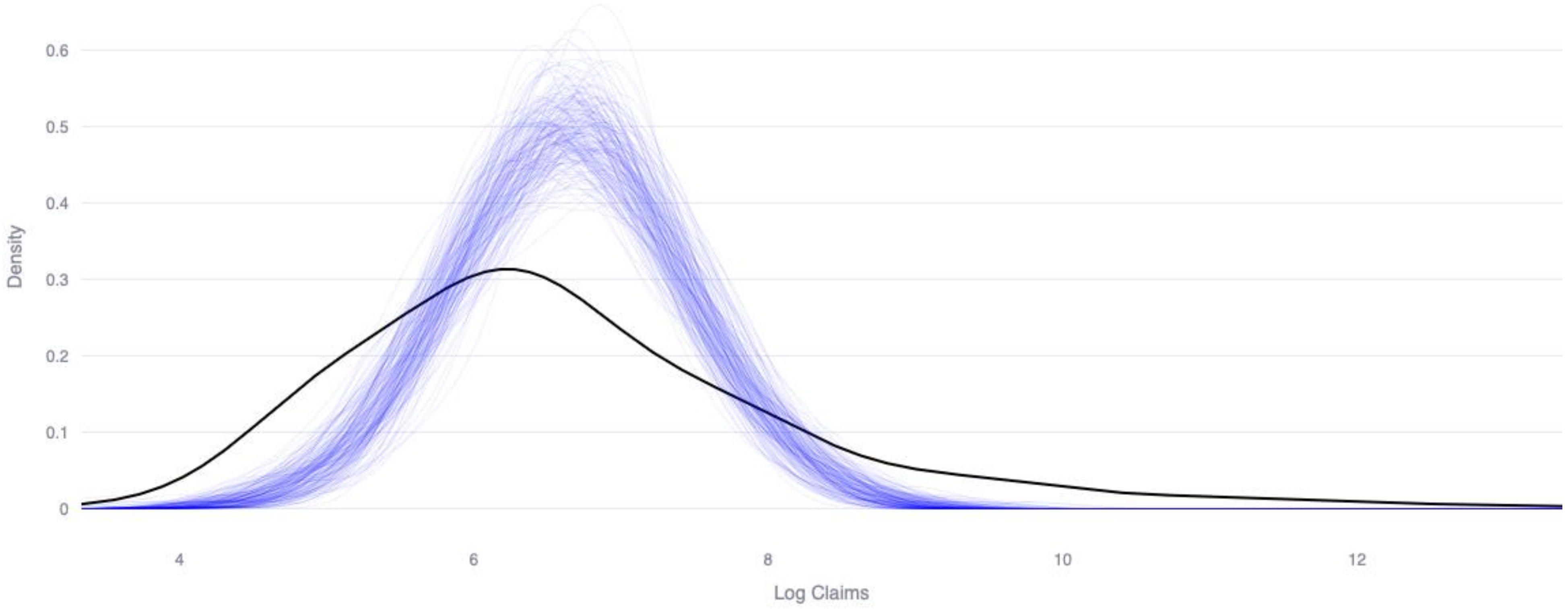
Class A03 severity: The lognormal assumption is not as good



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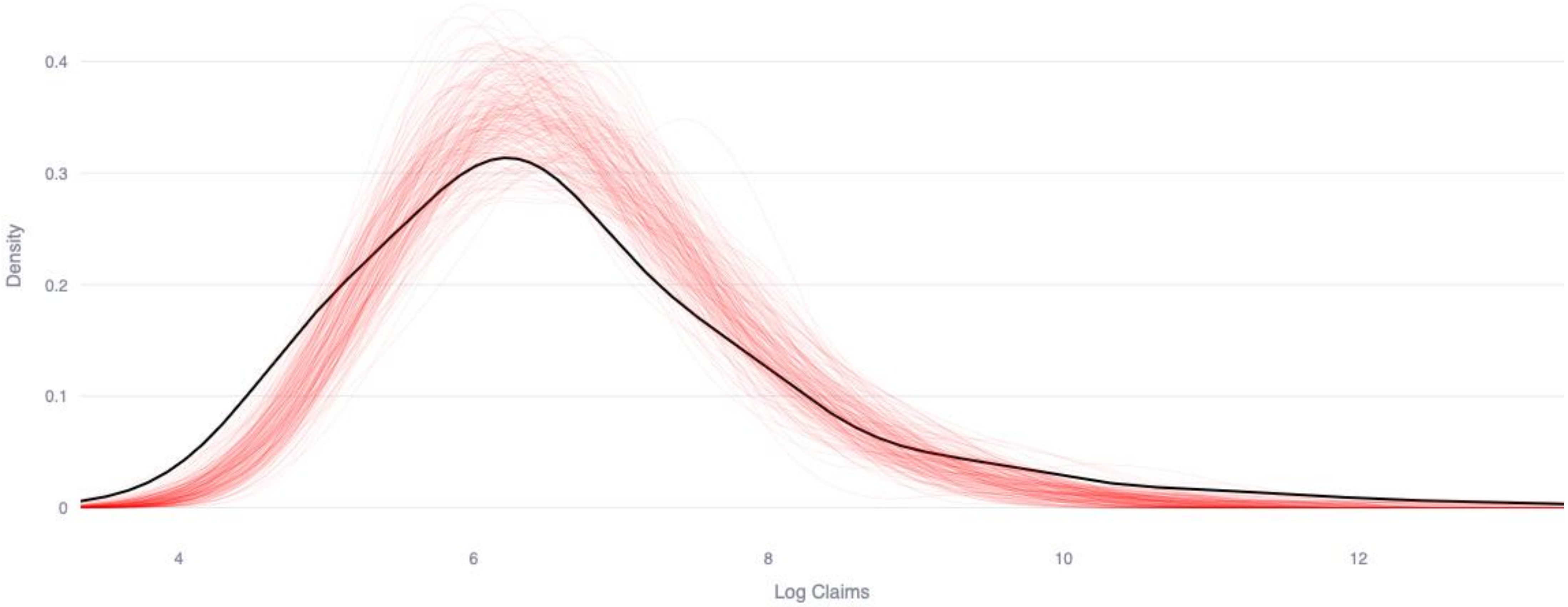
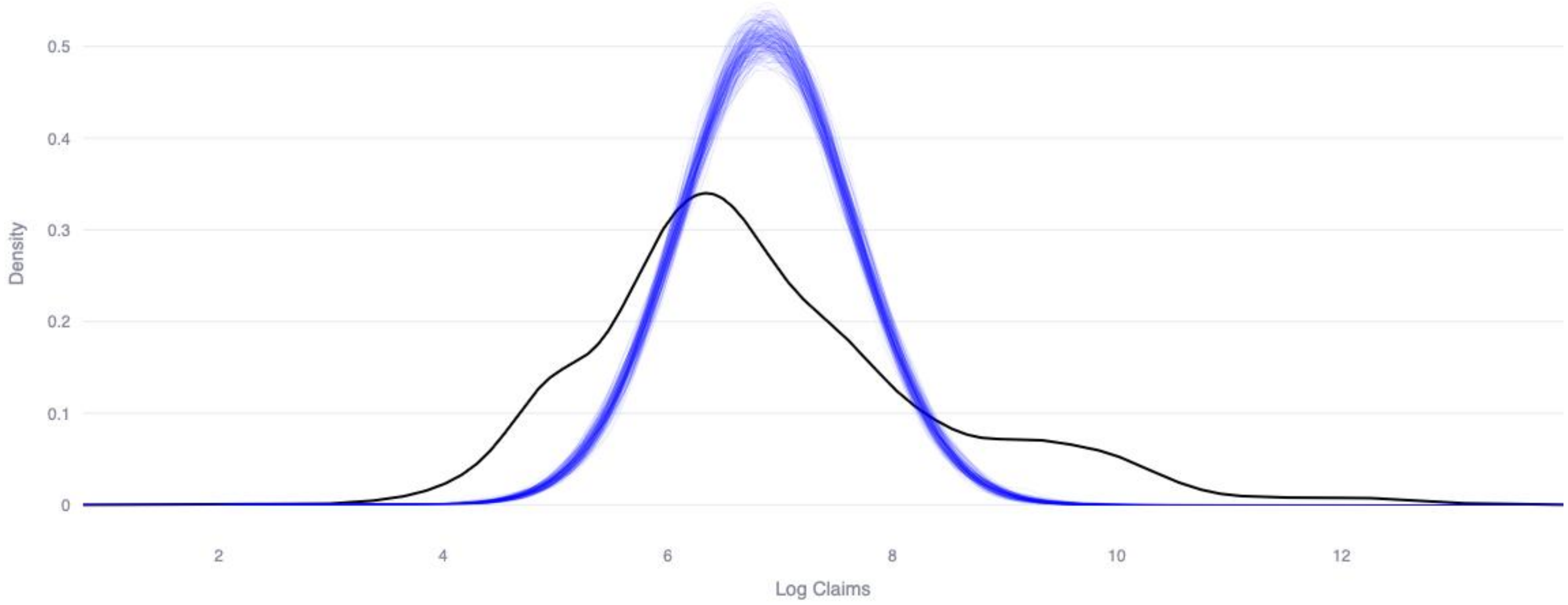
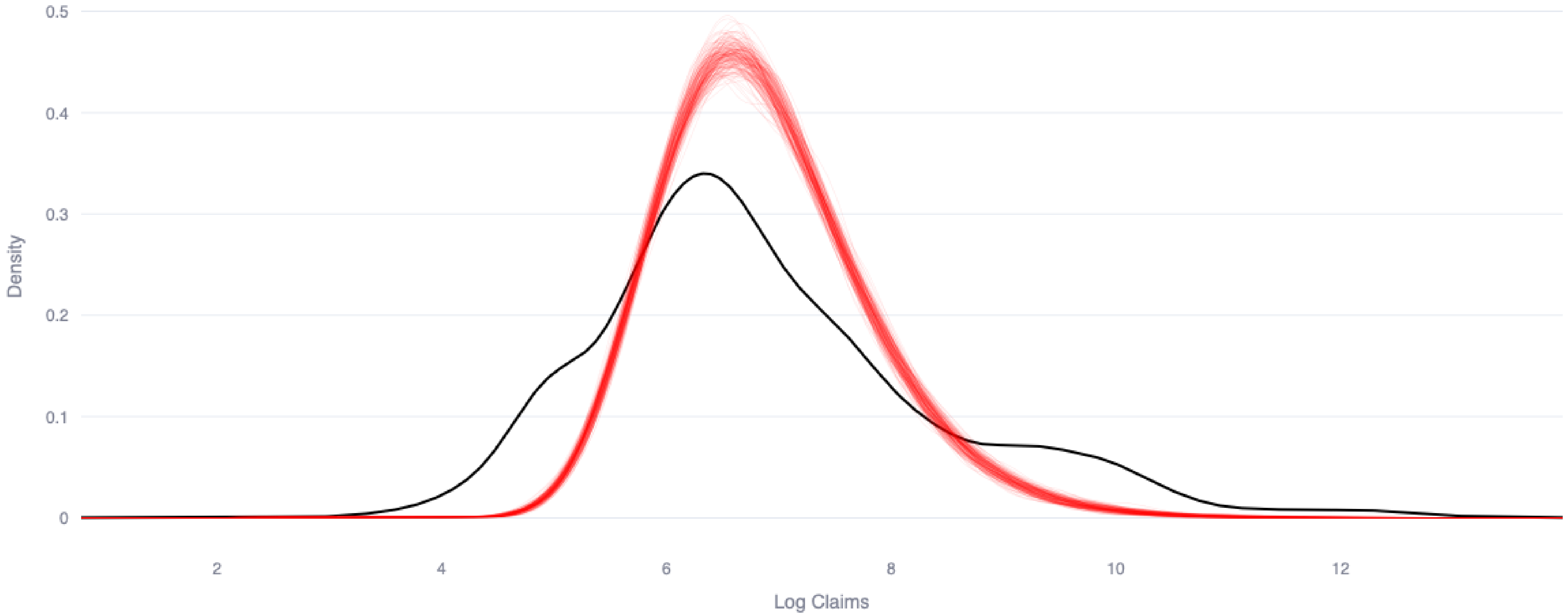
In the search of a better severity assumption: Beta Prime



Lognormal – Class A19



Not all nuances are captured by the new model



Reaching new heights in Jewell’s Bayesian Escalator

- Bayesian modeling enables **flexible, continuous model development**, with programming languages as PyMC and Stan.

Jewell, W. S. (1990). *Up the misty staircase with credibility theory.*

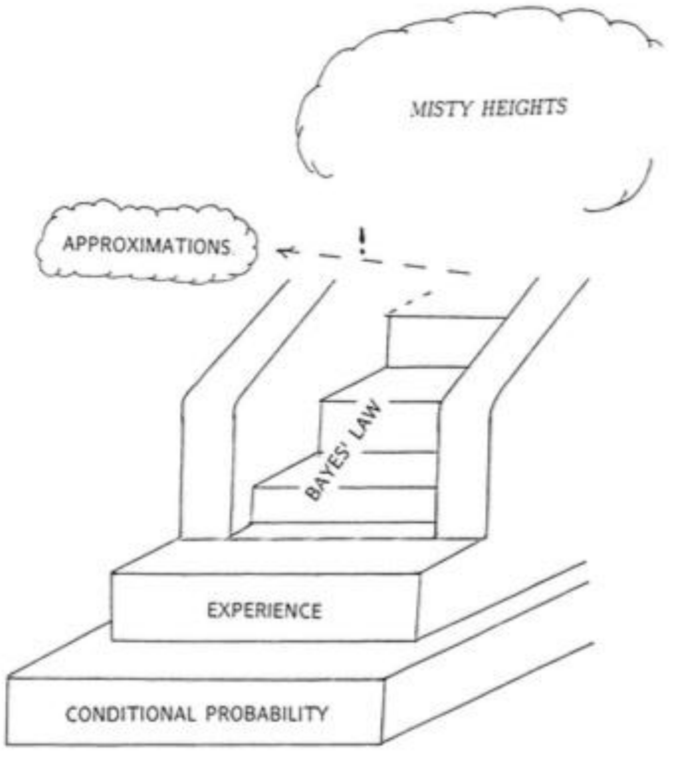


Figure 3 The Bayesian Escalator

Speakers

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