OliverWyman

TRANSITION TO A CODE-BASED ENVIRONMENT

The MCMC Use Case

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ACTUARIAL CONSULTING

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OVERVIEW

Transition to a Code-Based Environment

- Current State, i.e., Microsoft Excel
- The need to evolve
  - Statistical capabilities
  - Competition
- In this session, you will learn "how to evolve"

The MCMC Use Case

- Actuaries are in the business of modeling uncertain outcomes.
- There are (at least) three sources of uncertainty that should be considered:
  - Process Risk
  - Parameter Risk
  - Model Risk
- MCMC fitting provides the actuary with information on parameter risk
- In this session, you will learn:
  - MCMC Basics (Terminology, Tools)
  - Why MCMC; Why Now
  - Example Model
  - Evaluation
  - Application

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TRANSITION TO A CODE-BASED ENVIRONMENT

THE CURRENT STATE

ASTIN 2016 Report on Non-Life Reserving Practices
https://www.actuaries.org/ASTIN/Documents/ASTIN_WP_NL_Reserving_Report1.0_2016-06-15.pdf

NORTH AMERICA

USA

Full member association

Population: 318.7 million
Insurance premiums: MUSD 1,280,443
Non Life premiums: MUSD 752,222
NL premium/capita: USD 2,360
Local GAAP: ☐ Discounting ▩ Appointed/signing actuary
Respondents market share: ▯▯▯▯▯

Country report by
Chandu PATEL
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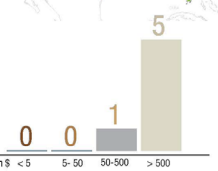
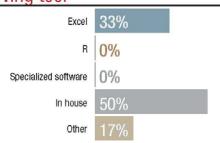
Respondent companies size



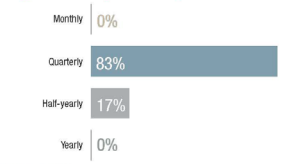
The US Non-life or Property/Casualty market is the largest market in the world, with many varied and sophisticated exposures subject to review by Property/Casualty actuaries. Due to the specialized nature of the market, actuaries who review these exposures are Members of Casualty Actuarial Society. In order to review and provide a formal opinion on property/casualty reserves, specific educational and experience requirements are in place. Actuaries are required to follow certain Actuarial Standards of Practice and a Code of Professional Conduct in their professional work and these are promulgated by the American Academy of Actuaries. The range of exposures analyzed by Property/Casualty actuaries varies from motor/automobile liability and physical damage, workers' compensation to professional liability such as medical malpractice. The legal framework in place in the US makes the actuary's task more challenging.

In the US, Company management is responsible for the amount of booked reserves and the actuary evaluates the reasonability of the booked reserve in the context of his/her estimates, which typically includes a range of estimates. Although the market share of the Companies that participated in the survey is small given the large market, the Companies represent a good cross-section of the US/Bermuda industry since they include insurance/reinsurance and small/large companies.

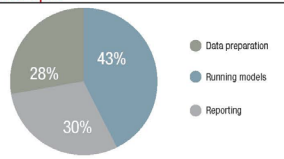
Reserving tool



Reserving exercise periodicity



Resources split



ASTIN

1. Standard claims: triangle-based technologies

		Main method	Peer method	Informational	Unused
DETERMINISTIC	Percentage	0%	0%	33%	67%
	Loss ratio	83%	17%	0%	0%
	Chain ladder	100%	0%	0%	0%
	Bornhuetter-Ferguson	100%	0%	0%	0%
	Cape Cod	0%	33%	17%	50%
	Average cost	17%	17%	17%	50%
	De Vylder	0%	0%	0%	100%
	Fisher-Lange	0%	17%	0%	83%
	GLM	0%	0%	0%	100%
	Munich Chain Ladder	0%	0%	0%	100%
STOCHASTIC	Market-based std dev	20%	0%	0%	80%
	Internal calibration	20%	0%	0%	80%
	Mack	33%	0%	17%	50%
	Merz & Wüthrich	0%	0%	0%	100%
	GLM	0%	0%	0%	100%
	Bootstrap / CL	40%	0%	0%	60%
	Bootstrap / BF	0%	0%	0%	100%
	RJMCMC	0%	0%	0%	100%

2. Standard claims: individual claims-based technologies

	Main method	Peer method	Informational	Unused
Percentage	0%	0%	0%	100%
ICR (Antonio-Plat)	0%	0%	0%	100%
ICR (Chalrot-Gremillet)	0%	0%	0%	100%
ICR (other)	0%	0%	0%	100%

3. Other claims

Annuities	N/A	100%	Deterministic math. reserves	0%	Other modalities	0%
Asbestos	N/A	50%	Survival Ratio	25%	Other modalities	25%
Disability/workers comp.	Experience tables	50%	N/A	50%	Other modalities	0%
Decennal/contruction liab.	Other	50%	N/A	50%	Other modalities	0%
Credit	N/A	100%	Regulatory	0%	Other modalities	0%

4. Adjustments / misc.

Past inflation	Not treated	67%	Flat assumption	33%	Other modalities	0%
Future inflation	Not treated	50%	Flat assumption	50%	Other modalities	0%
Discounting	Duration-based	40%	Dvt patterns-based	40%	Other modalities	20%
Discount type	Yield curve	60%	Flat rate	40%	Other modalities	0%
Development patterns	Chain ladder/paid	100%	De Vylder	0%	Other modalities	0%
Diversification effect	Correlation matrix	50%	Not calculated	33%	Other modalities	17%
Large claims	Treated separately	50%	Treated jointly	50%	Other modalities	0%
Reinsurance / retrocession	Proportional assumption	33%	Other	33%	Other modalities	33%
Subrogations	Not calculated	50%	Projection of net triangles	50%	Other modalities	0%
Ibnr contract allocation	Not allocated	80%	Split using weights	20%	Other modalities	0%
Equalization reserve (local)	No eq. reserve	100%	Calculated	0%	Other modalities	0%
Risk Margin	Projected	40%	Not calculated	40%	Other modalities	20%
Ibnyr and Ibner differenciation	No	83%	Yes	17%	Other modalities	0%
Reserves ranges (R.R.)	No range, only Actuarial BE	50%	Actuarial BE+reserves range	50%	Only reserves range	0%
Booked Reserves	Mostly Actuarial BE	50%	Actuarial BE	33%	Seldom Actuarial BE	17%
Methods used for R.R.	Alternative methods	40%	Only Actuarial BE	20%	Changes in assumptions	20%

THE NEED TO EVOLVE

Train Your People to Think in Code by David Waller (MIT Sloan Management Review, April 11, 2019)
https://sloanreview.mit.edu/article/train-your-people-to-think-in-code/

- Today, most companies **equate doing analysis with writing formulas in spreadsheets**. But the business landscape has shifted seismically since the invention of the spreadsheet. Today, organizations must think in terms of millions of individual customers, not just a handful of segments, and solve problems with reusable solutions to avoid reengineering the process from the ground up. And they want to **benefit from the latest advances in machine learning and AI, not simply throw regressions at whatever analytical problem they face.** In short, companies need to retrain for writing code, not formulas, as **the future of work will entail thinking not just analytically but also algorithmically**.
- Taking a code-centered approach will benefit organizations in three ways:
  - First, thinking in code allows companies to **cleanly separate data from analysis of the data, which allows teams to improve each one independently of the other**. When data and analysis are cleanly separated, different teams can focus on independently improving each aspect, leading to faster progress.
  - Second, **code is much easier to share and reuse** — the entire open-source software movement rests on this idea. Software developers have spent years building tools to make their work easy to trace, modify, and share. By adopting key principles of software development, such as version control, enterprise teams can be more efficient and collaborative as updates to files are tracked throughout their lifetime and changes can be reversed easily.
  - Finally, **code is better for both simple and complex analysis**. Breakthroughs in machine learning and AI techniques are implemented as code, and by cloning the code researchers are using, individuals can gain **access to state-of-the-art techniques in analysis, quickly and for free**.

THE NEED TO EVOLVE

RStudio Webinar: Why Your Enterprise Needs Code-First Data
https://www.rstudio.com/resources/why-your-enterprise-needs-code-first-data-science/

- Advantages of a Code first view
  - Flexible: Not a black box
  - Iterative: Feedback loops to support change
  - Reusable and **extensible**: Efficiency and toolbox development
  - Inspectable: Tracking and auditing when combined with a version control system
  - Reproducible: Allows for rerunning and verification
- Pitfalls of codeless data science
  - Difficulty tracking changes: Why, When, Who
  - Single source of truth: Is this the most recent file
  - Difficulty monitoring and auditing work
  - Difficulty reproducing work

THE NEED TO EVOLVE

Contingencies: Is 'Data Science' an Existential Threat for Actuaries? (January/February 2020)
https://contingencies.org/data-science/

- I recall boarding an airplane in the early 1990s and finding myself seated next to an actuary who, almost a decade earlier, had been one of my first managers after I entered the profession. He had recently moved to a new company in another part of the country, and I asked where that company generally recruited actuarial students. His response? **Recruitment of actuarial students was a low priority for his new company, as spreadsheets had made them mostly obsolete. Later in the conversation, he acknowledged that he had made that remark half in jest—but only half.**
- In any case, in recent years, entry-level employment opportunities for actuaries have not grown as quickly as the number of people pursuing them, leading a recent candidate for the Board of Governors of the Society of Actuaries—an actuary who teaches actuarial science in a West Coast university—to observe that the "actuarial job market for students is difficult, with the number of candidates significantly outstripping available jobs."
- The exact distinction between what data scientists do and what other, longer-established professions that deal with the analysis of data do is **NOT** (added by me) an elusive one.
  - The data scientist has a broader toolset.
  - The actuary has better domain knowledge.
  - Who wins?

HOW TO EVOLVE

Train Your People to Think in Code by David Waller (MIT Sloan Management Review, April 11, 2019)
https://sloanreview.mit.edu/article/train-your-people-to-think-in-code/

- Companies should aim to select at most two, but ideally one, analytical programming language as a company-wide standard — something everyone can “speak.”
- Create shared-code repositories. Once people transcribe ideas in a common language, companies should take a cue from open-source communities and establish their own shared-code repositories and knowledge bases.
- A good way to get going quickly is to pick a project, create a code repository around it, and invite contributions from a wide audience.

HOW TO EVOLVE

Train Your People to Think in Code by David Waller (MIT Sloan Management Review, April 11, 2019)
https://sloanreview.mit.edu/article/train-your-people-to-think-in-code/

- **Make code part of business as usual.** Companies that want to generate the most value possible from advanced analytics face one final, and daunting, challenge: They must **make code-based modeling the rule, not the exception**. It must become business as usual, as unremarkable and reflexive as attaching a spreadsheet to an email. What makes this challenge formidable is that it **requires not just a change in perspective but also a change in habits**. But there are **pragmatic strategies** for accelerating this shift.
- Companies that truly view analytics as a strategic priority will go to great lengths to communicate clear and specific expectations at all levels. **Senior executives broadcast company-wide messages emphasizing their belief in and renewed focus on analytical excellence.**
- A second strategy for making this change happen quickly and smoothly is to **protect and provide time for employees to get training**
- A third and powerful tactic is **setting up a viable support structure**. People need to know whom to ask for help; the angst of learning can be considerably lowered when that help is timely and relevant. Progress stalls when the same handful of individual super-users are questioned repeatedly.

HOW TO EVOLVE

This is my slide!

- Create **Standard Operating Procedures** to help your team code consistently, facilitate collaboration, and define best practices
- Navigate licenses
- Establish and manage repositories to share code between teams and projects. There are many benefits to using cloud repositories:
  - Set up change approval processes and email alerts
  - Provide a “source-of-truth” and enforces its use as changes occur
  - Enable teams to leverage each other’s work instead of rebuilding similar projects or re-fixing related bugs
  - Set up template projects to facilitate SOP adoption
- Replace Existing Processes with code-based approaches that can leverage modern tools.
- Create templates consistent with corporate visual identity will empower your team to create code-based, automated documents
- Data processing: create repeatable and customizable data pipelines with code.
- **Training**
- **Senior Management Buy in**

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THE MCMC USE CASE

TWO MAJOR SCHOOLS OF STATISTICAL THINKING ARE FREQUENTIST AND BAYESIAN STATISTICS

Frequentist Statistics

- Observations are repeatable random events
- **Parameters are fixed**
- Objective view on probability
- Calculate the probability of observing events based on distribution given a set of parameters
- Less computationally intensive

Bayesian Statistics

- Observations are a known fixed sample
- **Parameters are unknown**
- Subjective view on probability
- Describe parameters probabilistically based on observations and prior assumptions
- Computationally intensive
- **Actuaries are inherently Bayesian**

ACTUARIAL MODELS ARE DESIGNED TO ASSESS RISK, BUT A FREQUENTIST APPROACH LACKS A KEY COMPONENT OF RISK

- The key components of risk are that should be considered are:
  - Process Risk: The projection of future contingencies are inherently variable
  - Model Risk: Models used are not representative of the specified risk or appropriate to the circumstances
  - Parameter Risk: Parameters used are not representative of future outcomes

- Typical **stochastic** actuarial models consider model risk and capture process risk, however many lack parameter risk.

BAYESIAN STATISTICS CAN IMPROVE ACTUARIAL MODELS BY INCORPORATING PARAMETER RISK

- Data is fixed
- Prior assumptions can allow for the incorporation of prior knowledge (a.k.a. actuarial judgement)
- Technological advances have made Bayesian modelling more accessible

Bayes Theorem

$$P(Y \mid X) = \frac{P(X \mid Y) * P(Y)}{P(X)}$$

$$= \frac{f(X \mid Y) * f(X)}{\int_{-\infty}^{\infty} f(Y \mid X) * f(X)\, dx}$$

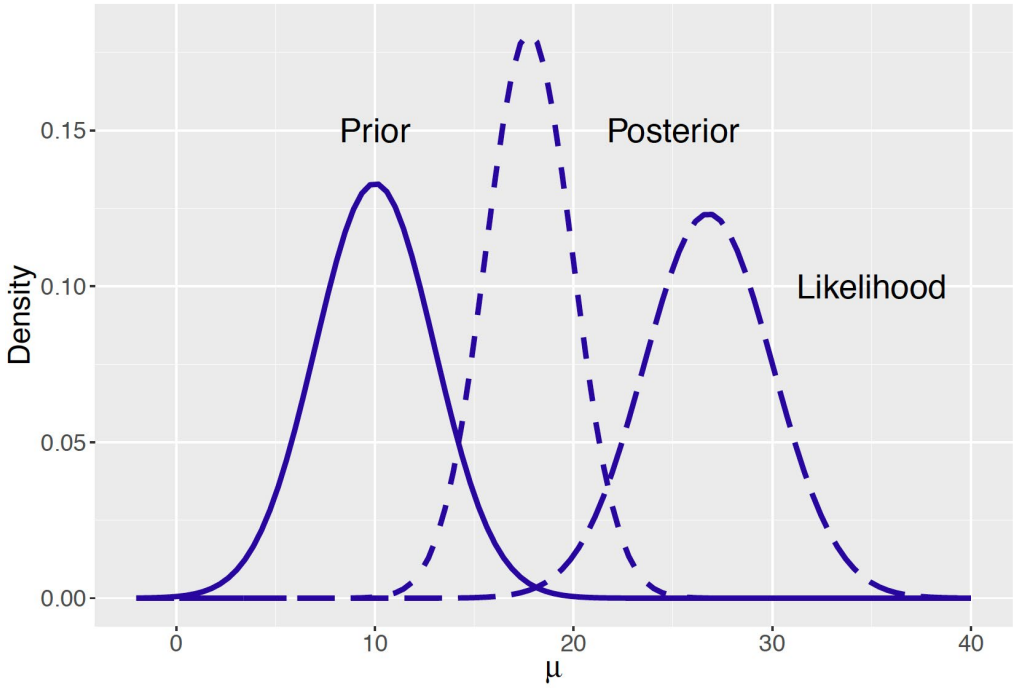
$$= \frac{f(\text{data} \mid \theta)\, f(\theta)}{\int f(\text{data} \mid \theta) f(\theta)\, d\theta}$$

MARKOV CHAIN MONTE CARLO (MCMC) IS AN EFFECTIVE WAY OF USING BAYESIAN STATISTICS IN ACTUARIAL MODELS

- Markov Chain is a process by which predictions can be made regarding future outcomes based solely on the present state
- Monte Carlo is a method which relies on repeated random sampling to obtain quantitative results
- Putting Markov Chain and Monte Carlo theory together, MCMC is a to gather a representation of the true but incalculable posterior distribution via simulation and repeated sampling
- There are 3 popular MCMC algorithms:
  - Metropolis
  - Gibbs
  - **Hamiltonian**

THE COMPONENTS OF MCMC MODELS ARE THE DATA, PRIOR ASSUMPTIONS, LIKELIHOOD AND POSTERIOR DISTRIBUTION

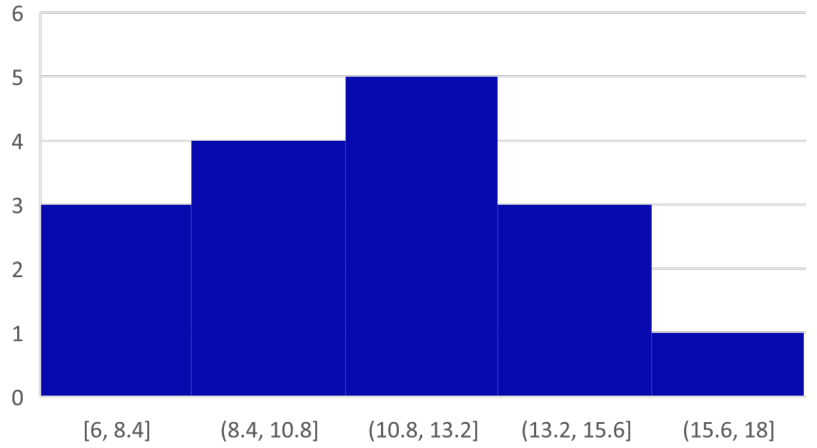
- The data – our factual understanding of events that have occurred. Fixed.
- Prior assumptions – our belief about the potential parameter space that could have led to the data.
- Likelihood - our belief about the distribution from which the results arose.
- Posterior Distribution – the resulting combination of the above three elements.



AN EXAMPLE OF MCMC MODELLING CAN BE USED TO FORECAST THE NUMBER OF CLAIMS

- The **Data** – our observed historical claim counts

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Counts	6	18	10	11	11	14	10	15	11	8	12	14	11	9	7	9



- **Likelihood** – a Poisson distribution.
- **Prior** assumptions – Our prior belief is that the rate is around 9 which we express as Normal(9, 2)

AN EXAMPLE OF MCMC MODELLING CAN BE USED TO FORECAST THE NUMBER OF CLAIMS

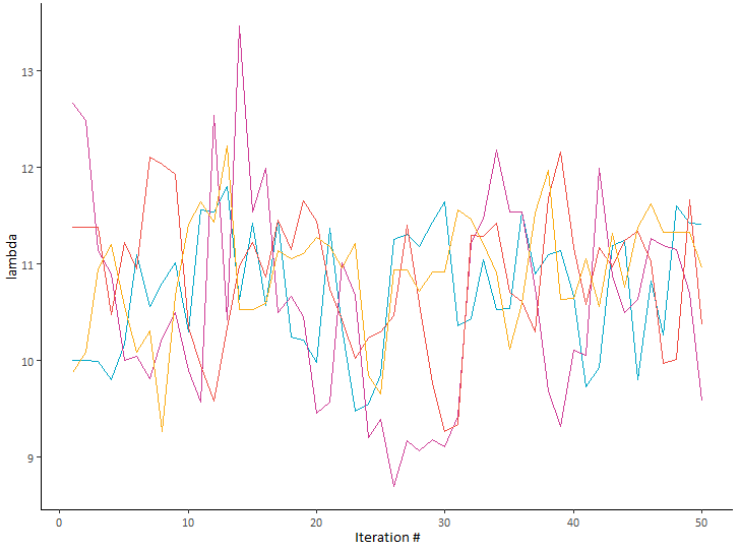
```
data{
  int<lower = 1> N; //Number of observations
  int<lower = 0> obs[N]; //Observations
}

parameters{
  real<lower = 0> lambda; //Parameter lambda
}

model{
  lambda ~ normal(9, 2); //Prior for lambda

  for(n in 1:N){
    obs[n] ~ poisson(lambda); //Observation model fit
  }

}
```

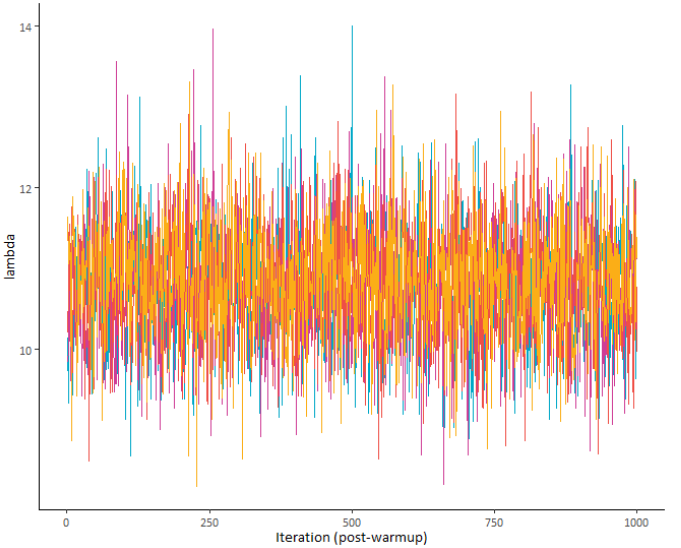
VALID INFERENCES FROM SEQUENCES OF MCMC SAMPLES ARE BASED ON THE ASSUMPTION THAT THE SAMPLES ARE DERIVED FROM THE TRUE POSTERIOR DISTRIBUTION OF INTEREST

- A few things to look for when evaluating a good MCMC fit:
  - High effective sample size (N_{eff})

$$N_{eff} = \frac{N}{1+2*\sum_{1}^{Inf}\rho_i}$$

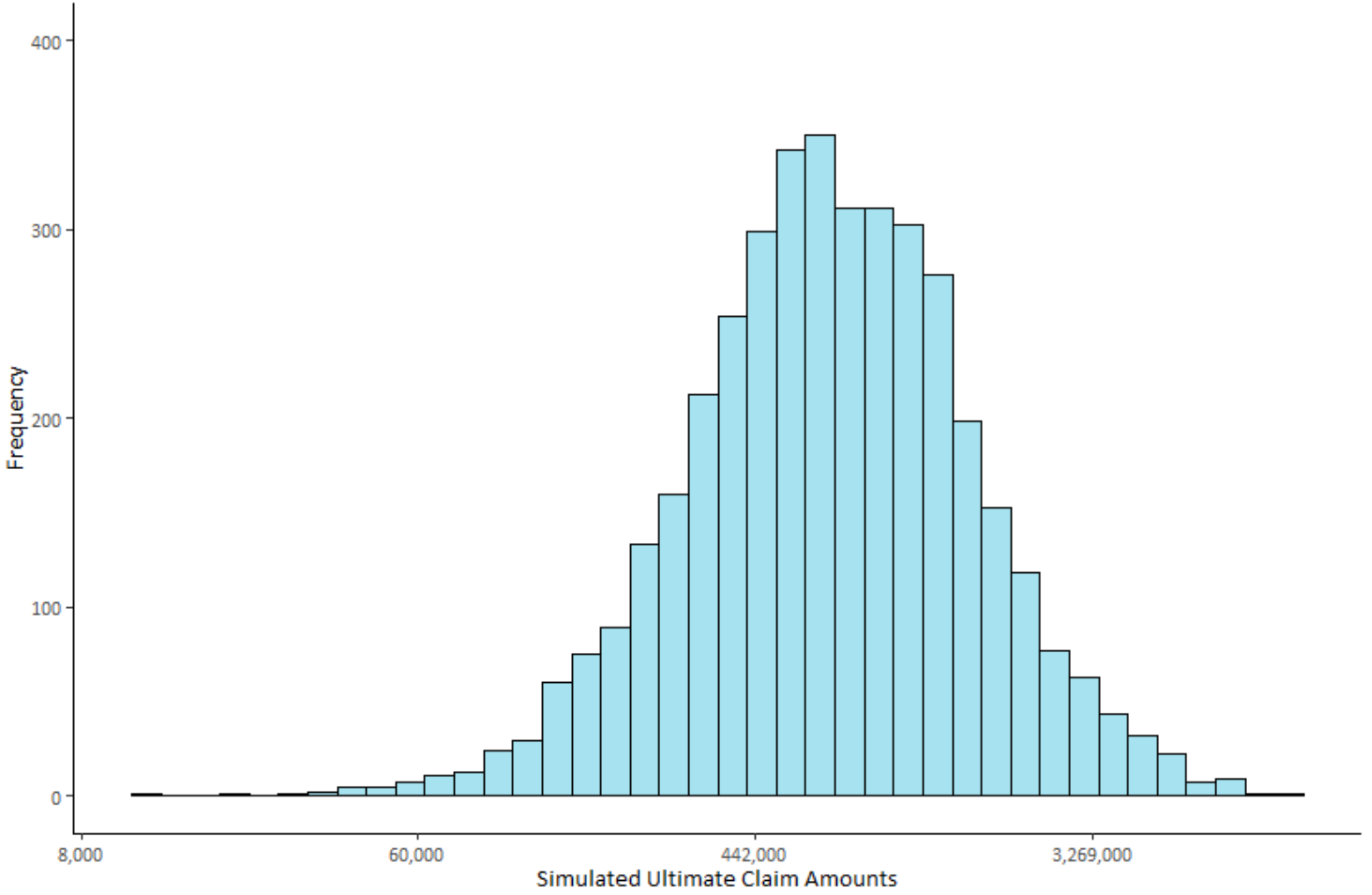
  - Convergence Diagnostic ($\widehat{R}$) close to 1.00
  - Convergence
  - Well mixing chains



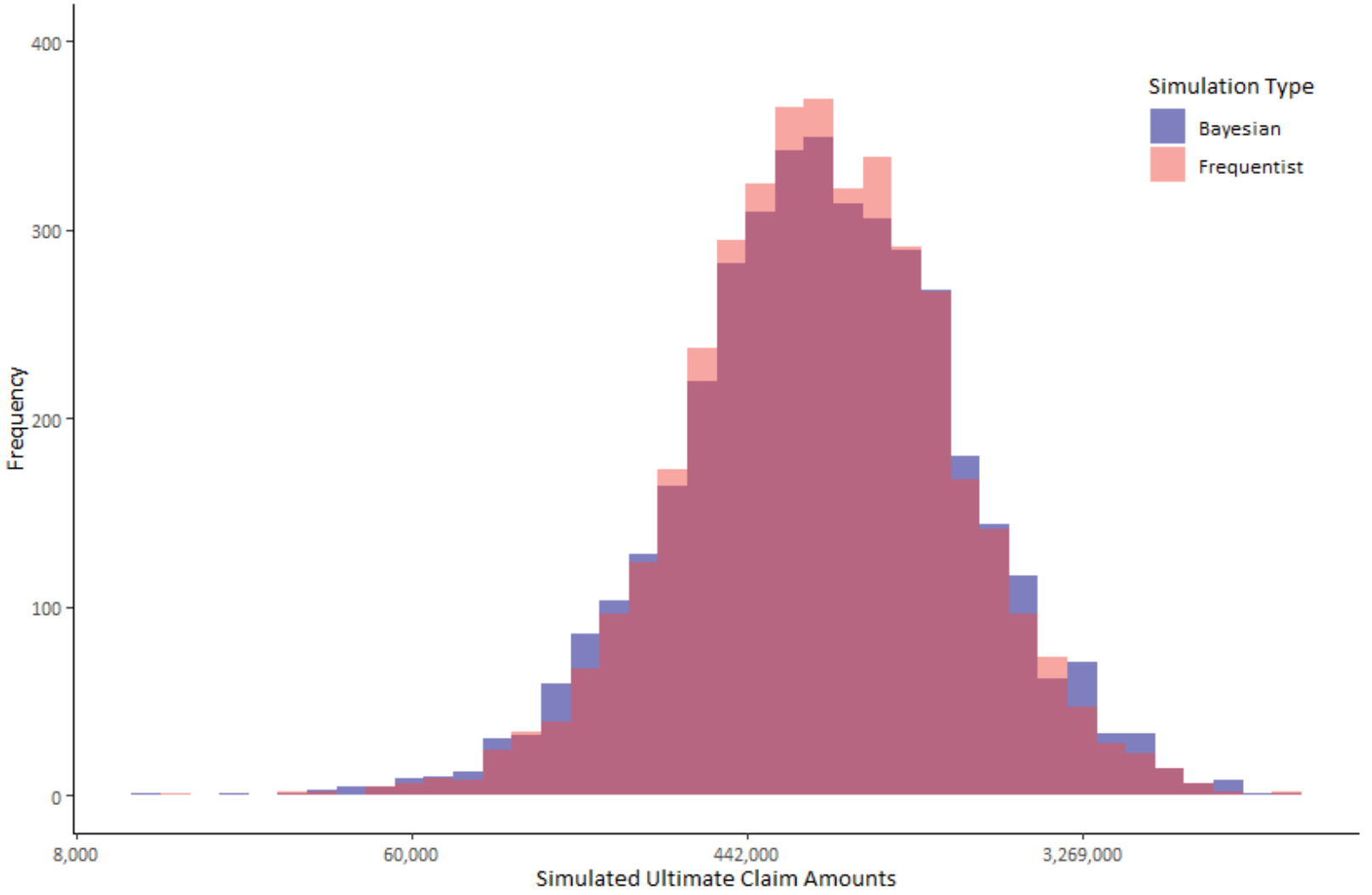


N_{eff}	1246.855
$\widehat{R}$	1.005

EXTENDING MCMC TO VARIOUS COMPONENTS OF ACTUARIAL MODELS CAN CREATE A FORECAST USING SOLELY BAYESIAN STATISTICS



COMPARISON OF BAYESIAN AND FREQUENTIST MODELS SHOW SIMILAR RESULTS, BUT BAYESIAN MODELS HAVE INCORPORATED PARAMETER RISK



MCMC WITH STAN IS JUST ONE EXAMPLE OF EMPLOYING BAYESIAN STATISTICS

BAYESIAN STATISTICS ISN'T JUST A SET OF METHODS, IT IS A WAY OF THINKING AND APPROACHING ANALYSES

- Additional resources to learn more about Bayesian statistics:
  - Ford, P., "MCMC Algorithms," CAS Study Note, Version 0.7, November 2019
  - McElreath, R., Statistical Rethinking: A Bayesian Course with Examples in R and Stan, 2nd edition, CRC Press, March 2020.
- Additional resources to learn more about Stan:
  - Stan Reference Manual
  - Stan Functions Reference

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