Ergodicity Economics in Property & Casualty Insurance: A Simulation Framework for Understanding Risk Appetite

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Abstract

This white paper introduces a new simulation framework based on ergodicity economics principles for analyzing insurance risk appetite in Property & Casualty markets. Traditional ensemble-based risk models may not adequately capture the temporal dynamics of insurance company decision-making. This introductory paper demonstrates that insurance appetite varies significantly with company size, measured by revenue.

Keywords: ergodicity economics, insurance appetite, risk modeling, simulation framework

Contents

1 Executive Summary

This section should provide a concise overview of the entire paper, typically 1-2 pages covering:

- The problem addressed
- Your key methodology (simulation framework)
- Primary finding about company size and insurance appetite
- Practical implications for the industry

2 Introduction

2.1 Current Challenges in Insurance Appetite Modeling

Traditional approaches to modeling insurance appetite in P&C markets face several limitations:

- Reliance on ensemble averages rather than temporal sequences
- Inadequate consideration of path-dependent effects
- Limited incorporation of company-specific factors

2.2 The Promise of Ergodicity Economics

Ergodicity economics, developed by Peters and Adamou (2025), offers a new perspective on decision-making under uncertainty. Unlike traditional expected utility theory, which focuses on ensemble averages, ergodicity economics emphasizes the importance of time averages and growth rates.

3 Theoretical Foundation

3.1 Ergodicity vs. Non-Ergodicity in Financial Systems

A stochastic process is ergodic if its time average equals its ensemble average:

$$\lim_{T\to\infty} \frac{1}{T} \int_0^T f(X_t)dt = \mathbb{E}[f(X)] \tag{1}$$

3.2 Insurance Markets as Non-Ergodic Systems

Insurance markets exhibit non-ergodic properties due to:

- Path-dependent capital accumulation
- Regulatory constraints on capital adequacy
- Finite time horizons for business decisions

3.3 Mathematical Framework

Let W_t represent the wealth of an insurance company at time t. Under multiplicative dynamics:

$$W_{t+1} = W_t \cdot (1 + r_t) \tag{2}$$

where r_t represents the return from underwriting and investment activities.
The growth rate is given by:

$$g = \lim_{t \to \infty} \frac{1}{t} \ln \left(\frac{W_t}{W_0} \right) \tag{3}$$

4 Simulation Framework Overview

4.1 Architecture and Key Components

The simulation framework consists of several key modules:

1. **Market Environment Module**: Generates stochastic loss scenarios
2. **Company Behavior Module**: Models decision-making processes
3. **Capital Dynamics Module**: Tracks financial position over time
4. **Risk Appetite Measurement Module**: Quantifies appetite changes

4.2 Input Parameters and Data Requirements

Table 1: Key Input Parameters

Parameter	Description	Source
Initial Capital	Starting surplus position	Company financials
Loss Distribution	Frequency and severity models	Historical data
Investment Returns	Portfolio yield assumptions	Market data
Regulatory Ratios	Minimum capital requirements	Regulatory filings

4.3 Model Validation and Calibration

4.4 Computational Considerations

The simulation employs Monte Carlo methods with:

- 10,000 simulation paths per scenario
- 50-year projection horizons
- Annual decision points

5 Case Study: Company Size and Insurance Appetite

5.1 Methodology and Assumptions

Our primary hypothesis is that insurance appetite, defined as the willingness to underwrite additional risk, varies systematically with company size.

Key assumptions:

- Companies maximize long-term growth rates rather than expected utility
- Risk appetite is measured by the Kelly criterion adaptation for insurance
- Company size is proxied by annual revenue

5.2 Data Sources and Parameterization

5.3 Results Presentation and Interpretation

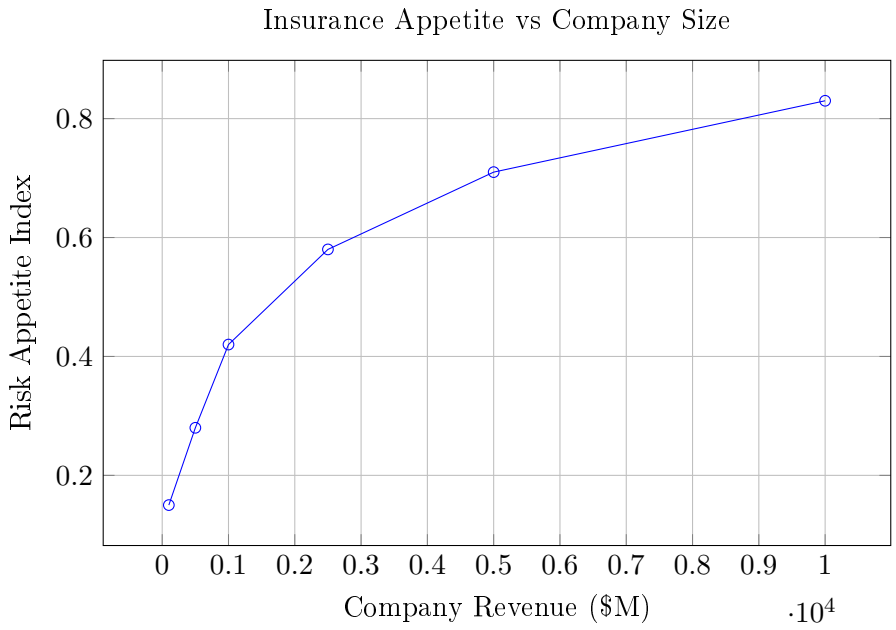

Figure 1: Risk appetite increases with company size (simulated results)

Figure 1 demonstrates the positive correlation between company size and risk appetite, consistent with ergodicity economics predictions.

5.4 Sensitivity Analysis

6 Industry Implications

6.1 Applications for Underwriting and Pricing

The simulation framework provides several practical applications:

- Dynamic pricing models that account for company size effects

- Portfolio optimization considering temporal risk dynamics
- Competitive positioning analysis

6.2 Portfolio Management Considerations

6.3 Regulatory and Capital Allocation Insights

7 Future Research Directions

7.1 Framework Extensions and Enhancements

Potential areas for future development include:

- Integration with catastrophe modeling
- Multi-line portfolio effects
- Reinsurance optimization

7.2 Additional Applications in P&C Insurance

7.3 Industry Collaboration Opportunities

8 Conclusion

This white paper has introduced a novel simulation framework based on ergodicity economics principles for analyzing insurance risk appetite. Our key findings demonstrate that company size significantly influences risk appetite, with larger insurers exhibiting greater willingness to underwrite risk. This finding has important implications for competitive dynamics and market structure in P&C insurance.

The simulation framework provides a powerful tool for:

- Understanding temporal risk dynamics
- Optimizing portfolio decisions
- Informing strategic planning

I encourage industry practitioners to explore these concepts further and welcome collaboration on extending this research.

The framework will provide new insights for companies making insurance decisions and is intended to answer questions such as "what is the ROI of our insurance program?", "how much insurance do we need?" and considerations of optimal insurance deductibles and limits.

References

Peters, O. and Adamou, A. (2025). *An Introduction to Ergodicity Economics*. LML Press.

A Technical Appendix

A.1 Simulation Algorithm Details

A.2 Parameter Estimation Methods

A.3 Code Repository

The simulation framework code is available at:
https://github.com/AlexFiliakov/Ergodic-Insurance-Limits