Auto Insurance Pricing Fairness Model

Regulatory Evaluation Summary Report

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1. Purpose of This Report

This report provides a regulatory-style assessment of a synthetic auto insurance pricing model, following the analytical and communication standards used by the Alberta Automobile Insurance Rate Board (AIRB). The goal is to demonstrate how a regulator evaluates:

- Model performance
- Fairness and potential bias
- Segment-level impacts
- Consumer implications
- Appropriateness of pricing variables and assumptions

This project uses fully synthetic data for demonstration only.

2. Dataset Overview

The dataset consists of 30 synthetic auto insurance policy-year records. Exploratory analysis shows:

Driver Demographics

- Ages range from **19 to 75**
- Young drivers (<25) and older drivers (>65) show higher pure premium volatility
- Middle-aged drivers (25–40) show the lowest pure premium

Vehicle & Rating Variables

- Vehicle types: Sedan, SUV, Coupe, Truck, Hatchback
- Territories: Urban and Rural
- Coverage types: Collision, Comprehensive, Third Party

Premium & Loss Patterns

- Premiums range from **$600 to $2,100+**
- Claim costs are heavily right-skewed, with many zero-claim years and several large losses
- Pure premium variation is driven primarily by severity

This structure is representative of real-world auto insurance rating factors.

3. Modeling Approach

Two predictive models were developed to estimate **pure premium** (claim cost per exposure).

3.1 GLM-Style Linear Regression (Baseline Model)

Used as the main transparency-aligned baseline for fairness evaluation.

Model Performance:

- **MAE:** 1,536.54
- **R^2:** –1.81

This negative R^2 reflects the small dataset and the volatility of claim severity—typical challenges in insurance modeling.

3.2 Random Forest Regressor (Non-Linear Benchmark)

Provides a comparison model capable of capturing non-linear effects.

Model Performance:

- **MAE:** 1,359.17
- **R^2:** –1.41

The Random Forest performs better than the GLM baseline but still yields a negative R^2 due to the limited dataset and extreme claim variability.

4. Key Findings from Exploratory Analysis

4.1 Driver Age

- **<25:** Highest pure premium volatility
- **25–40:** Lowest and most stable pure premium

- **40–65:** Moderate risk, some large losses
- **65+:** Higher severity and variability

This pattern reflects typical risk progression across age groups seen in actuarial practice.

4.2 Premium Distribution by Vehicle Type

- **Coupes** and **Sedans** have the highest average premiums
- **Trucks** have the lowest premiums
- **SUVs** fall in the mid-range

These patterns align with expected industry pricing behaviour.

4.3 Claim Frequency and Severity

- Claim severity is highly skewed, with most observations at zero
- A few large claims (>$4,000) create high pure premium values
- Comprehensive shows the highest frequency in this synthetic sample
- Third Party has the lowest frequency but includes severe losses

4.4 Territory Differences

Average claim cost results:

- **Rural:** ~2,100
- **Urban:** ~1,050

Rural segments show approximately **double** the severity of Urban policies, consistent with longer travel distances and higher average impact speeds.

5. Fairness & Bias Considerations

5.1 Age-Based Fairness

- Higher premiums for young drivers (<25) are actuarially justified
- Middle-aged drivers (25–40) show favourable experience

- Older drivers (65+) exhibit higher severity; this segment requires monitoring in real filings

5.2 Territorial Fairness

- Higher severity in Rural segments appears risk-based
- Due to small sample size, these effects require credibility review

5.3 Coverage Type

- No evidence of unfair discrimination among coverage types
- Patterns follow typical insurance behaviour

6. Model Appropriateness

Despite weak performance metrics, the models:

- Reflect the correct methodology
- Capture general insurance patterns
- Provide a baseline for fairness analysis
- Are suitable for demonstration and portfolio examples

However:

- They are **not** suitable for real-world pricing decisions
- Additional data, multi-year experience, and more granular segmentation would be required for regulatory submission

7. Consumer Impact Considerations

If these patterns represented real data:

- Young and older drivers may face affordability challenges
- Rural consumers could experience higher premiums due to elevated severity
- Model instability could cause pricing volatility across segments

A regulator would likely require additional support, data, or credibility adjustments before approving rate changes based on such a model.

8. Recommendations

1. **Increase data volume**, ideally multi-year and multi-policy.
2. Consider **GLM enhancements** (Tweedie distribution, interactions).
3. Apply **credibility adjustments** to mitigate high-severity outliers.
4. Expand segmentation (e.g., driver experience, vehicle symbols).
5. Perform **residual analysis** to detect systematic biases.
6. Provide **consumer-friendly summaries** for transparency.

9. Conclusion

This synthetic demonstration successfully mirrors core AIRB regulatory evaluation processes, including:

- Model performance assessment
- Fairness and segmentation review
- Consumer impact considerations
- Interpretation of actuarial and statistical patterns

The project demonstrates regulatory-aligned thinking, analytical rigour, and understanding of the public-interest mandate embedded in insurance oversight.