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Analysis of the Factors Affecting the Financial Performance of Insurance Companies using Statistical Modeling

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Abstract

The insurance industry is fundamental to the global economy, accounting for about 7% of the gross domestic product (GDP) in numerous developed nations and serving a crucial function in risk management and financial stability. Recent years have seen escalating economic pressures that have adversely affected the profitability of insurance firms. These Difficulties encompass escalating inflation rates, a surge in claims, and losses attributable to natural disasters, with swings in interest rates that have impacted investment returns and the valuation of financial portfolios. This study aims to examine the determinants influencing the financial performance of insurance businesses through precise statistical models, with a particular emphasis on return on equity (ROE) as a principal metric. The research utilized real-time data encompassing characteristics such as insurance density, interest rates, underwriting capacity, and insurance expenditures, among others. Statistical modeling was employed to ensure the degree to which these factors influence profitability. The project seeks to establish an analytical framework to improve the efficiency of underwriting and pricing decisions. It further advances academic literature by utilizing sophisticated analytical tools to understand profitability dynamics inside the insurance sector.

Keywords: Analytical framework; financial performance; insurance industry; machine learning; statistical techniques

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1. Introduction

The insurance industry has an essential importance to the world economy and plays a role as stabilizing force which allows individuals, businesses or both managing risk protection their assets or long-term development investment. By Liedtke In 2024 alone, the property and liability insurance sector in the United States underwrote over $975 billion in direct written premiums-- roughly 7% percent of GDP, according President, the National Association of Insurance Commissioners (NAIC). By Liedtke Four insurance companies--State Farm, Progressive, GEICO (a subsidiary of Berkshire Hathaway), and Allstate--together account for more than 31 percent of U.S. market share, demonstrating their strong position in auto and life insurance. In such a context of linked financial and related risk factors, the insurance business face steadily increasing profit volatility, see Mills etal. As difficulties of various kinds arise, major finance companies are working together to solve a few of the most pressing problems. The insurance industry is becoming more aware of certain driving factors influencing either its own or its partners' particular operational and financial performance problems. By Sayre While traditional statistical models have provided rudimentary analysis, machine learning techniques present an opportunity to find complex patterns, forecast profitability and assist with decision-making at all levels, see Boppiniti and Rane etal. This study seeks to compare insurance company financial performance with the assistance of both statistical methods and machine learning models in order to understand what aspects greatly affect profitability and so to establish accurate predictive models based on real financial and operational data. Profitability is one of the most important indicators of the financial performance of insurance companies, reflecting the company's ability to generate returns from its insurance and investment operations, by Worku etal. The Profitability of

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an insurance firm is primarily dictated by the disparity between total revenues and costs, which indicates the net financial result of operational and investment endeavors, see Katopodis. A key indicator for evaluating profitability is the Return on Equity (ROE), determined by dividing net profit by the company's equity, which indicates the efficiency of generating returns from shareholders' investments. In property and liability insurance, the Combined Ratio, which combines the loss ratio and the expense ratio as a proportion of written premiums, serves as a crucial indication of underwriting performance. A ratio under 100% indicates underwriting profitability, whereas a ratio beyond 100% denotes possible losses. Consequently, sustaining insurance profitability requires a meticulous balance between precise premium pricing, efficient claims and administrative expense management, and insuring stability. An economic indicator that reflects the level of insurance penetration in the market and its correlation with the size of the insurance portfolio, by Nebolsina. This represents the ratio of claims to premiums; the higher this ratio, the lower the profitability, see Hasibuan etal. Machine learning is one of the most prominent artificial intelligence tools used to analyze big data and discover hidden patterns, see Chaudhary etal. It is particularly suitable for application in the insurance sector due to the multiplicity of variables and complex relationships.

The extent to which a company retains risk before resorting to reinsurance; the higher the limit, the higher the risk incurred, by Pallaria. These represent the costs of selling and managing insurance policies, see Pillay etal. This individual contract cancellation behavior needs to be solved to build stability in the financial foundation for the longer term. While this is an extensive research topic in the domain specific to deterministic insurance, as far as we are aware not many statistical investigations have been carried out on predicting future expenses due to contract termination, by Nebolsina. For an insurance company it is a very handy thing indeed to be able to predict contract discontinuation rates at the level of on specific contracts, so that they know exactly what modifications they need to make in order not losing them, see Groll. A profitability indicates that a company can generate profit all activities of the business. It shows you how good the management is in creating profits using every resource they have.

This represents a company's financial capacity and affects its credit rating and market confidence, by Shaheen etal.

This directly affects the profitability of insurance companies, especially in light of interest rate fluctuations, see Mazreku etal. Statistical models are used to analyze the relationship between study variables and understand their impact on financial performance, see Belas.

This paper is divided into the following sections: theoretical framework and literature review methodological research in descriptive data analysis model analysis and results findings from the models.

2. Previous related studies

Big Data technologies are changing; the way how insurance companies collect, store, process and translate data to the new conditions. Accordingly, they are diffusing through many spaces of insurance coverage: threat evaluation, buyer analytics, product creation, advertising and marketing analytics, see Katopodis. Claims evaluation, underwriting evaluation, fraud detection and reinsurance see Sivarajah etal. In life insurance underwriting companies thoroughly assess the risk profile of each individual applicant, by Ngunguni et al. It is the job of the underwriting company to have accurate risk assessments and insurance premium calculations for operations to continue unhindered or without needing support. The term reference of risk stratification is primarily in use of insurance companies, which are typically buyers' classification across a spectrum having their historical data as an input to determine the losses see Cummins et al. As per Ahmed etal (INSURANCE helps in the smooth operation of business environment as it is difficult for organizations to handle many risks specially which are foreseeable in ever changing global economy. D'Apolito, Roth & Wiedl (2021) find that bigger more profitable and in general healthier insurance firms may have the most compass in ESG. As a result, the bank is creating its climate change impact, both so-called on-balance sheet and off-balance sheet. This direct influence results from the operations of the bank and can be thought as the impact that could negatively affect climate, and environmental sustainability, see Hasibuan etal. The native's impact would be indirect from their transactions or those emissions financed by the risks and relationships with entrusted counterparties of which that credit institution is part. Guler (2016) discuss on the determinants of return on equity of Takaful and Non- Takaful insurance companies in Pakistan over the pre-crisis period (i.e. 2003-2006), crisis period (i.e. 2007-2009) and post-crisis period (i.e. 2010-2013). We used panel regression to investigate the influence of several factors on profitability. The results imply that profitability of sub-insurance industry in Pakistan was not hindered by the movements of the macroeconomic variables in all three periods because overall economic structure of the country is on developmental stage which may be rendering conventional macroeconomic correlations with profitability inapplicable, by Pallaria. This experience allows to further the understanding of the underpinnings of a variety of machine learning strategies and how they work in various industries energy, healthcare, finance, autonomous driving, e-commerce etc by Shaheen etal. This article will provide

a valuable reference for academic researchers, data scientists and machine learning engineers in choosing different types of data and extraction methods for their varied needs, identifying suitable machine learning algorithms to tackle their specific issues as well as anticipating the possible outcomes, see Mazreku etal. By identifying specific corporate factors (independent variables) including liquidity, company size, company age, tangible assets, leverage and equity this research paper assesses their effect on the return on assets (ROA) and net profit margin (NPM) in relation to profitability measured using this dependent variable. The Ahmeti sample for this study includes 11 insurance companies from 2015 to 2020. The results of the regression analysis show that company size, leverage and age are significantly affect to ROA. The size of a company and its expansion is the factor that affects significantly in ROA indicator among insurance companies of Kosovo. Sasidharan (2014) used panel data methodologies in order to analysis the effect of eleven micro variables on the financial performance of general insurers in India, see Sasidharan.

3. Methodology of Research

This study is to analyze the financial performance of some insurance businesses with real-time data. Determine the operational and financial aspects that significantly influence the profitability of insurance companies, including loss ratio, capital, investment returns, and expenses.

- Evaluate the profitability performance of several insurance businesses using quantitative metrics and examine profitability trends.
- Utilize statistical models and machine learning methodologies to identify concealed patterns among variables and forecast future financial outcomes.
- Create a predictive model for insurance company executives to enhance pricing and underwriting strategies.

The research employs a quantitative analytical methodology and encompasses the subsequent steps:

a. Data Acquisition

Utilize authentic data from annual corporate reports (2019–2024) encompassing the subsequent variables: Net Profit, Capital, Underwritten Premiums, Loss and Compensation Disbursed, Loss Ratio, Retention Constraints, Return on Investment Insurance Density, Expenditures and Commissions, Descriptive Statistical Analysis Summarize the attributes of the variables utilizing means, standard deviations, temporal trends, and boxplots/line charts.

b. Correlation Examination

Assessing the correlation between several variables and profit margin or return on equity. Employing Statistical Techniques Implementing and Evaluating Models Such As: Regression Analysis, Dynamic Time Warping (DTW).

- Dependent Variable: Return on Equity (ROE)
- Independent Variables: Loss Ratio, Return on Investment, Retention Threshold, Compensation and Expenditures, Principal, Insurance Density

4. Analysis and Discussion of Results

Variables: Capital (Billion $), Loss Rate (%), Total Compensation (Billion $), Claims Paid (Billion $), Retention Limit (Million $), Investment Interest Rate (%) , Insurance Density ($).

The heatmap Fig. 1 displays the pairwise Pearson correlation coefficients among the principal financial and operational indicators for leading U.S. insurance businesses from 2019 to 2024.

Capital exhibits a moderate positive association with the Investment Interest Rate (0.51). The Loss Rate exhibits weak or negligible connections with all variables. Insurance Density exhibits a negative correlation with various financial measures, particularly Total Compensation (–0.32). The majority of correlations are quite weak, indicating constrained linear interactions.

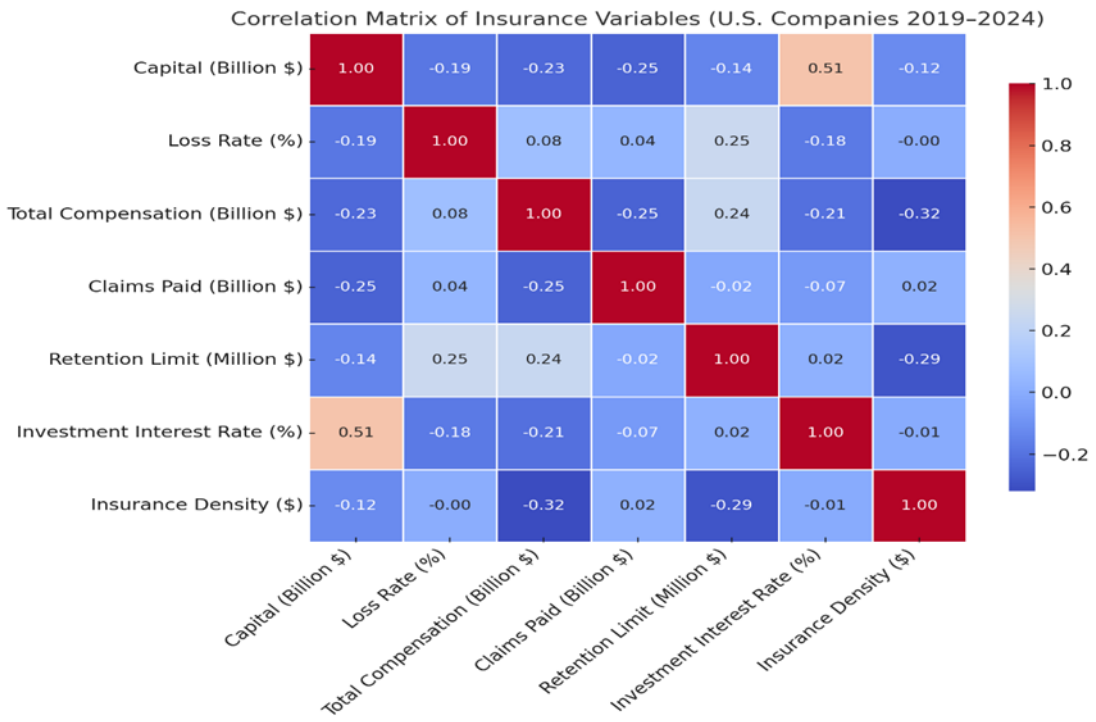

Fig. 1. Correlation Matrix Insurance Variable (U.S. Companies 2019-2024)

Table 1 shows that the Investment Interest Rate (IIR) has the lowest average (3.171%) and a relatively narrow range (2.8), indicating that this indicator is relatively stable across companies.

Insurance Density has an average of 1268.3, with a range of 620, indicating some variation among companies in the extent of insurance penetration among the population or market.

Capacity has the highest range of all variables (382,347), with a mean of 73,926, indicating high variability and the potential for outliers.

Insurance Expenses and Commissions have an average of 8,777, with a range of 11,030, reflecting significant variation among insurance companies in the costs associated with issuing policies.

Capital for Insurance Companies has an average of 189.8, with a range of 635.8, indicating significant variation among companies in the level of allocated capital. The average loss rate is 69.14% and the range is 76.94, indicating a wide variation in compensation performance compared to written premiums, with the potential for companies with very low or near-zero losses.

Total compensation has the second highest range (45,644) with an average of 14,220, reflecting significant differences in the amount of compensation paid.

Table 1. The statistical summary of the data for each variable among the four insurance companies

Variables	Mean	Minimum	Maximum	Range
Investment interest rate	3.171	2.1	4.9	2.8
Insurance density	1268.3	1020	1640	620
Capacity, which represents the total premiums from the local market.	73926	35026	417373	382347
Insurance expenses and commissions	8777	3815	14845	11030
Capital for insurance companies	189.8	15.9	651.7	635.8
Loss rate	69.14	0.76	77.7	76.94
Total compensation	14220	11	45655	45644
Retention limits	339.6	150	500	350

Retention limits average 339.6 with a range of 350, reflecting varying policies among companies regarding the amount of risk they retain before transferring it to reinsurance. Progressive has the highest average capacity of 117,129, indicating a large volume of operations or resources.

Allstate has the lowest average, at 44,506, indicating a more conservative level of operating capacity.

In terms of stability, Allstate's data shows the smallest range of variation (20,833) between the minimum (35,026) and maximum (55,859), reflecting relatively stable performance.

Progressive represents the most volatile company in this index, with a wide range of 371,266 between the minimum (46,107) and maximum (417,373) values, which may indicate the presence of outliers or exceptional fluctuations in the data.

State Farm had the highest average insurance and commission expenses (11,300), which may reflect its operational expansion or a more aggressive marketing policy. In contrast, Berkshire Hathaway had the lowest average (4,786), with the smallest range of variation (1,832), reflecting stable expenses and clear operational efficiency. Progressive had the highest variability (8,716), which may indicate fluctuations in its cost structure or changes in its business model over the period.

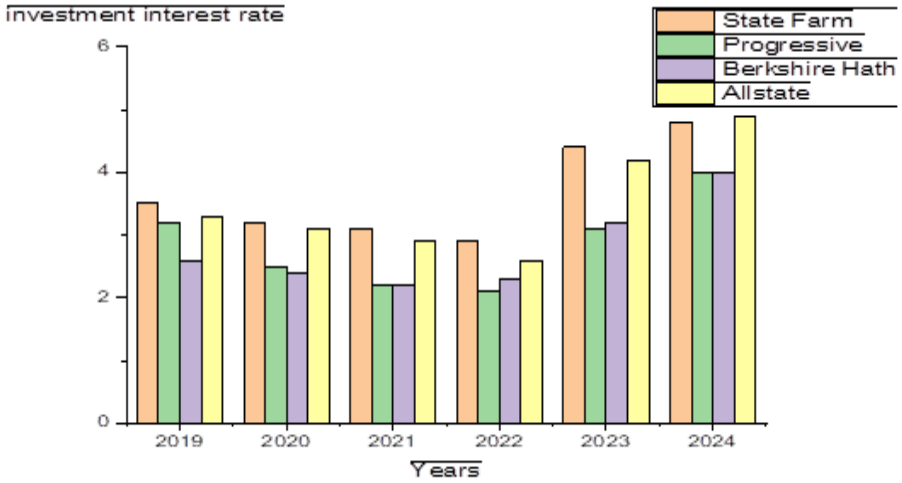

Fig. 2. Bar chart of investment interest rate for four American Company over the period 2019–2024.

Berkshire Hathaway had the highest average capital (515.9), reinforcing its position as one of the largest players in the market. Allstate had the lowest average (22.95), which may indicate a relatively smaller operating size. Progressive was the most volatile (412.7), which may be attributed to significant changes in its funding levels or reinvestment policies. In contrast, State Farm demonstrated remarkable capital stability (range = 29). Three companies (Allstate, Berkshire, and Progressive) had a very similar loss ratio (~72.3), reflecting consistent claims management performance. However, State Farm had a much lower average (59.8) and a very low minimum (0.8), suggesting the possibility of an outlier or unusual event that should be investigated.

Berkshire Hathaway had the highest average (28,564), reflecting its commitment to paying claims and possibly the high value of its insurance policies. In contrast, Allstate had the lowest average (16.79), a strikingly low value that may indicate a difference in the unit of measurement or the scope of insurance coverage. It is worth noting that both State Farm and Progressive's data were characterized by significant volatility, reinforcing the hypothesis of extreme values or diversity in the insurance programs offered.

State Farm demonstrated complete stability in retention limits (Min = Max = 500), which may reflect a clear and consistent risk management policy. The lowest average was for Progressive (183.3), while Allstate and Berkshire recorded significant variation (range = 100), indicating greater flexibility or changes in reinsurance strategies.

This indicator showed overall stability across all companies, with averages ranging from 2.75% to 3.65%, and the overall range did not exceed 2.8%. State Farm recorded the highest average (3.65%), reflecting relative efficiency in portfolio management (Fig. 2).

Berkshire Hathaway recorded the highest average (1,335), while State Farm had the lowest (1,198.3). All companies were characterized by similar values and low variation, indicating stable premium volume relative to the insured population.

Fig.3. provides valuable insights into how Allstate's fundamental metrics have evolved over 2019 2024, which enabling the identification of patterns, fluctuations, or anomalies that may inform strategic decision-making or further econometric analysis

It shown that Relative stability across all companies indicating stable investment returns.

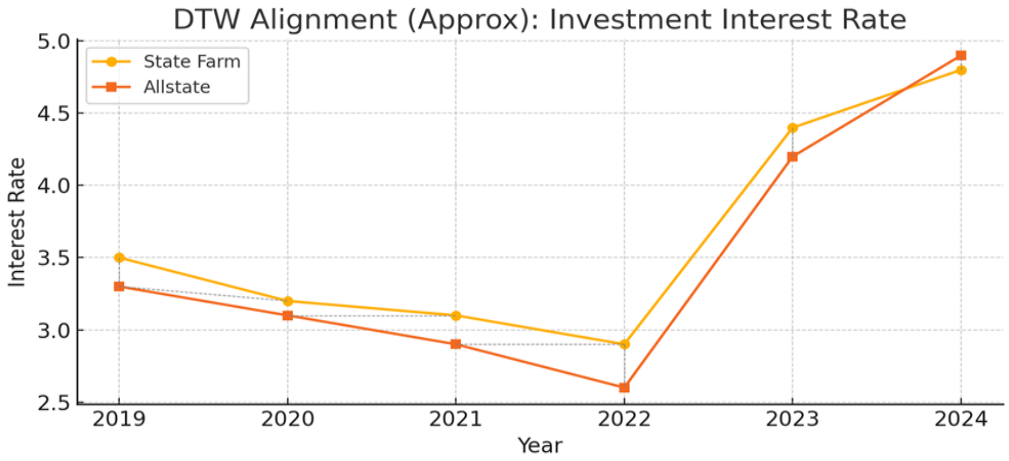

Fig. 3. The Dynamic Time Warping (DTW) gap between the investment interest rate time series of State Farm and Allstate from 2019 to 2024

The Dynamic Time Warping (DTW) gap between the investment interest rate time series of State Farm and Allstate from 2019 to 2024 is roughly 0.19, calculated using squared differences. The exceedingly low DTW distance indicates a robust resemblance in the trends and shapes of both series.
Notwithstanding minor annual fluctuations, both corporations had nearly identical trends in their investment interest rates.
This closeness may indicate overarching economic or industry-specific investment return trends impacting both organizations in a comparable manner.

Table 1. Independent Variables and Standardized Path Coefficients

Components	Standardized Effect on ROE	Interpretation
Insurance Density	2.050	Very strong influence
Interest Rate	1.757	Very strong influence
Capacity	1.238	Strong
Insurance Expenses	0.882	Moderate to strong
Loss Rate	0.496	Moderate
commissions	0.351	Mild to moderate
Capital	0.346	Weak to moderate
Retention Limits	0.290	Weak

An analysis of the standardized effects of the independent variables on return on equity (ROE) shows that insurance density is the most influential factor, with a value of 2.050, reflecting the importance of individual insurance penetration in enhancing insurance companies' profitability. The investment interest rate also shows a strong impact of 1.757, underscoring the vital role of portfolio management. Similarly, underwriting capacity had an impact of 1.238, indicating the importance of expanding gross written premiums to achieve higher financial returns. Insurance expenses and commissions recorded a moderate positive impact of 0.882, which may reflect the effectiveness of some of these costs in generating profitable sales. On the other hand, the loss rate showed a moderate impact of 0.496, potentially reflecting effective claims management or reinsurance programs. While Total Compensation (0.351), Capital for Insurance

Companies (0.346), and Retention Limits (0.290) recorded relatively weak effects, indicating that their direct impact on ROE may be limited or conditioned by certain organizational and contextual factors.

Table 2. Analysis of Variance for Return on Equity (ROE)

Source	DF	SS	MS	F	P
Regression	8	1584.53	198.067	3.19	0.025
Residual Error	15	930.77	62.051		
Total	23	2515.3			

The Partial Least Squares (PLS) Regression model on Table 3 demonstrates statistically significant evidence ($p = 0.025$) that the chosen eight financial variables substantially account for changes in Return on Equity (ROE) for insurance businesses. The model explains 63% of the variation in ROE, underscoring the significance of capacity, investment returns, insurance density, and associated financial measures in influencing profitability within the insurance industry.

Table 3. Model Selection and Validation for Return on Equity (ROE)

Components	Variance	Error	R-Sq
Capacity, which represents the	0.26852	1798.49	0.284982
Insurance expenses and commissions	0.4735	1510.50	0.399475
Capital for insurance companies	0.57849	1161.37	0.538278
Loss rate	0.74365	986.44	0.607825
Total compensation	0.84909	940.16	0.626225
Retention limits	0.92404	931.00	0.629867
investment interest rate	0.98215	930.87	0.629917
Insurance density	1	930.77	0.629957

The model selection procedure for elucidating Return on Equity (ROE) via PLS regression on Table 4 demonstrates a gradual enhancement in explanatory power (R^2) with the inclusion of latent components. The cumulative R^2 increases from 0.285 (with a single component) to 0.630 (with all eight components), demonstrating that the selected predictors jointly account for a substantial amount of the variance in ROE. Nevertheless, small improvements beyond the fifth component indicate a point of decreasing returns, supporting a streamlined model comprising around five components to optimize accuracy and model complexity. These findings underscore the significance of financial measures, including insurance density, investment interest rate, and underwriting capacity, in forecasting profitability in the insurance industry.

Table 4. The standardized regression coefficients

Components	Return on Equity (ROE)	Return on Equity (ROE) standardized
Constant	45.0424	0
Capacity, which represents the	0	0.35602
Insurance expenses and commissies	0.0016	0.5093
Capital for insurance companies	0.009	0.18578
Loss rate	-0.0944	-0.13976
Total compensation	-0.0001	-0.10955
Retention limits	-0.0767	-1.04866
investment interest rate	13.0791	1.03297
Insurance density	-0.0439	-0.76223

Analysis of the standardized regression coefficients in the PLS model on Table 5 indicates the crucial significance of: The investment interest rate exhibited the most significant positive effect, with a standardized coefficient of (+1.03297), affirming the critical role of investment methods in improving return on equity.

Insurance expenses and commissions exerted a substantial positive influence, evidenced by a coefficient of (+0.5093), signifying that these expenditures are frequently allocated towards productive endeavors like as marketing or expansion, hence enhancing financial performance

The underwriting capacity (total premiums) exhibited a positive standardized coefficient of (+0.3560), signifying that the expansion of underwriting and the enhancement of market share are determinants that foster increased returns. In contrast, the model demonstrates distinct adverse impacts for:

Retention limits had a pronounced negative standardized coefficient of (-1.04866), indicating the peril of firms maintaining elevated risk levels without sufficient reinsurance, so substantially diminishing their profitability. Insurance density exhibited an unforeseen adverse effect of -0.76223, potentially indicating market saturation or deficiencies in pricing and claims management strategies.

The loss ratio exhibited a moderately negative coefficient of -0.13976, and total claims shown a negative effect of -0.10955, underscoring the necessity of managing risk and minimizing unproductive claims to enhance profitability.

Table 5. Fits and Residuals for Return on Equity (ROE)

Components	Return on Equity (ROE)	Fits	Res	SRes
1	26.98	18.5934	8.3866	1.31527
2	30.86	16.3749	14.4851	1.98581
3	15.94	19.2834	-3.3434	-1.8595
4	3.85	10.2542	-6.4042	-0.9745
5	17.8	20.1021	-2.3021	-0.39275
6	31.07	25.8698	5.2002	0.86226
7	29.04	21.6673	7.3727	1.12502
8	33.48	34.7588	-1.2788	-1.25944
9	18.38	13.5284	4.8516	0.91071

The fit and residuals evaluation table for the ROE forecasting model on Table 6 reflects the model's ability to capture the overall trends in the data, with some notable deviations between the actual and predicted values, particularly in certain rows. For example, row 2 showed the largest positive residual, with the actual ROE value being 30.86 versus the predicted value of 16.37, resulting in a residual of +14.49 and a relatively high standardized residual (+1.99), which could indicate an outlier or an underrepresented case in the model. Row 4 recorded a significantly negative residual (-6.40) due to overestimation, but the standardized residual (-0.97) remained within the statistically acceptable limits. Overall, the standardized residuals ranged between -1.86 and +1.99, indicating the absence of critical outliers and no standard deviations exceeding ±2, reflecting an acceptable degree of consistency in model performance. The balance of positive and negative residuals also indicates the absence of systematic bias in the estimates, although the occurrence of some relatively large residuals in specific rows may reflect data patterns that need better representation to improve the model's accuracy.

5. Conclusion

The insurance sector plays a pivotal role in supporting economic stability by managing risks and enhancing the financial security of the productive and service sectors, thus contributing to the growth of the overall financial system. In this context, the study aimed to identify the factors influencing the return on equity (ROE) of insurance companies through standard regression analysis using the PLS model. The results showed that the investment interest rate (1.03), expenses and commissions (0.51), and underwriting capacity in the local market (0.36) were the most positively influencing factors, reflecting the importance of investment efficiency and market expansion. Conversely, the results revealed negative effects for both retention limits (-1.05) and insurance density (-0.76), calling for a review of retention policies and a balanced distribution of insurance products. The "Capacity in Local Market" variable clearly stands out as a strong predictor, with its standardized effect reaching 1.238. It achieved high time similarity with ROE. Using Dynamic Time Warping (DTW) analysis,) the gap between the investment interest rate time series of State Farm and Allstate from 2019 to 2024 is roughly 0.19, reflecting a close time pattern. The new in this research is the integration of traditional statistical analysis using the PLS model with time similarity measurement tools such as DTW, which enhances forecasting accuracy and reveals subtle time patterns not visible using linear methods alone. The study recommends adopting flexible investment policies, fine-tuning underwriting and retention strategies, and adopting advanced predictive models (such as LSTM or ARIMA-DTW) in future research, while expanding the sample to include regional markets for comparison and improving the efficiency of strategic decisions.

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