A Prediction-Oriented Analysis of Solvency Adequacy in Property Insurance Companies under China's C-ROSS II Framework

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Abstract. Under the risk-oriented regulatory framework, solvency adequacy has become a core indicator of the financial stability of insurance companies. Using panel data of Chinese property insurance companies from 2017 to 2024, this paper empirically examines the determinants of solvency adequacy under the implementation of the C-ROSS II regulatory regime. A fixed-effects panel model is employed to control for unobserved firm heterogeneity and time-invariant characteristics. The results show that underwriting profitability and investment returns significantly enhance solvency adequacy, while higher loss ratios exert a negative effect. Excessive reliance on reinsurance may weaken capital accumulation and constrain solvency levels. In addition, changes in the regulatory framework, captured by a regulatory dummy variable, have a significant impact on insurers' solvency positions. These findings highlight the joint role of firm-level operations, asset allocation, and regulatory constraints in shaping solvency adequacy, and provide empirical evidence for understanding insurers' capital management under the evolving regulatory environment.

Keywords: Solvency Adequacy; Panel Data Analysis; C-ROSS II

1 Introduction

With the implementation of China's second-phase C-ROSS framework and the adoption of the new insurance contract accounting standards, the operating behavior, asset allocation structure, and capital constraints of insurance companies have undergone significant changes. Under the risk-oriented solvency regulatory regime, solvency adequacy has become not only a core indicator for assessing insurers' risk-bearing capacity, but also an important basis for regulators to conduct differentiated supervision.[1] Consequently, existing empirical evidence on the determinants of insurers' solvency adequacy requires re-examination in the context of the evolving regulatory environment. Prior studies often suffer from limited timeliness and insufficient control for unobserved firm heterogeneity and time effects. Against this background, this paper employs panel data of Chinese property insurance companies from 2017 to 2024 and constructs a firm fixed-effects panel model to systematically examine the impacts of firm-

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level operating characteristics, asset allocation, and macroeconomic conditions on core solvency adequacy. In addition, a regulatory dummy variable is introduced to capture the structural effects induced by the implementation of the second-phase C-ROSS framework.

Existing studies on insurance solvency adequacy mainly focus on firm-level financial indicators[1], asset allocation characteristics[2], or macroeconomic factors, providing valuable empirical evidence on the determinants of insurers' capital adequacy.[3] However, most of the literature is based on earlier regulatory frameworks and static empirical settings[4][5], with limited consideration of regulatory regime shifts and their structural impacts on solvency outcomes. In particular, insufficient attention has been paid to the heterogeneity of insurers and the dynamic effects induced by the implementation of the second-phase C-ROSS framework. To address these limitations, this paper constructs a two-way fixed effects panel model that simultaneously controls for firm-specific and time-specific unobserved heterogeneity. By incorporating a regulatory dummy variable and updated firm-level data, this study not only reassesses the determinants of solvency adequacy under the new regulatory regime, but also enhances the forward-looking and predictive relevance of solvency risk assessment in the context of evolving prudential supervision.

2 Analysis of the Operating Conditions of the Property Insurance Industry Post C-ROSS Implementation

Over the decade following the implementation of C-ROSS, China's property insurance industry has transitioned from high-speed to steady growth.[6] Initially, the industry maintained a rapid growth rate exceeding 10% annually. However, as shown in Table 1, a significant shift in the growth engine occurred following the comprehensive motor insurance reform in 2020. Between 2022 and 2023, the growth rate stabilized at a relawtively lower level of around 6.7%, marking the industry's shift from pursuing scale expansion to focusing on high-quality development and structural optimization.

Table 1. Key Indicators of the Property Insurance Industry (2016-2023) (Source: China National Financial Regulatory Administration)

Year	Property Insurance Premium Growth Rate(%)	Comprehensive Solvency Adequacy Ratio (%)	Key Events and Phase Characteristics
2016	9.1	269.3	First year of formal C-ROSS operation; stable growth.
2017-2019	Avg. 10.6	273.4	ndustry in a phase of sustained relatively high-speed development
2020	7.12	277.9	Implementation of comprehensive motor insurance reform
2021	6.38	285.4	Deepening of motor insurance reform; increased proportion of non-motor business.

2022	6.66	236.3	Economic pressures; temporary decline in solvency adequacy.
2023	6.73	227.7	Stabilized growth; solvency remains adequate but under slight pressure.

The data reveals three prominent trends within the property insurance sector:

2.1 Steady Overall Development of the Property Insurance Industry Post-C-ROSS Implementation

Since the formal implementation of C-ROSS in 2016, although the property insurance premium growth rate has fluctuated, it has maintained an overall **positive growth** trend, with an average annual growth rate ranging between 6% and 11%. This indicates that under a more scientific and stringent regulatory system, the property insurance market retains sustained developmental momentum, and industry operations remain broadly stable.

2.2 The Solvency Adequacy Ratio Exhibits a Pattern of "Initial Increase and Stabilization, Followed by Recent Pressure"

- **2016–2021:** The comprehensive solvency adequacy ratio continued to rise (from 269.3% to 285.4%), reflecting enhanced capital management capabilities and improved risk resilience of insurance companies under the C-ROSS framework.
- **2022–2023:** The adequacy ratio experienced a decline (to 236.3% and 227.7%), potentially attributable to macroeconomic downturns, capital market volatility, and factors like motor insurance reform. Nevertheless, it remained significantly above the regulatory minimum (typically 100%), indicating that overall industry risks are controllable.

2.3 Industry Phase Characteristics: Transition from "High-Speed Growth" to "High-Quality Development"

- **2017–2019:** With an average annual growth rate of 10.6%, the industry was in a phase of high-speed development accompanied by gradual structural optimization.
- **Post-2020:** Growth slowed but became more stable. The industry shifted from a singular pursuit of scale to emphasizing a balance among **business structure, profitability, and risk management**, aligning with the "**risk-oriented**" regulatory direction promoted by C-ROSS.

3 Determinants of Insurer Solvency and Model Specification

Solvency stands as the cornerstone of an insurance institution's sound operation and a critical entry point for regulatory oversight. With the deepening implementation of China's second-phase C-ROSS framework, particularly the enhancement of consolidated

supervision and capital constraints, property insurance companies' capital structures, asset allocation, and risk exposures have been profoundly impacted.[8] Therefore, it is necessary to systematically investigate the determinants of property insurers' solvency and construct a corresponding analytical framework within this new regulatory context.

3.1 Internal Factors

As shown in Table 2, the factors influencing the solvency of property insurance companies are complex and diverse, which can be categorized into internal and external factors. Under the second-phase C-ROSS, which emphasizes capital authenticity and risk consolidation, the mechanisms through which these factors operate may have changed significantly compared to the past.

Table 2. Qualitative Analysis of Solvency Determinants

Indicator	Name	Expected Direction
X1	Loss Ratio (or Claims Ratio)	Negative
X2	Net Income to Total Revenue Ratio	Positive
X3	Investment Return Rate	Positive
X4	Reinsurance Ratio	Positive
X5	Return on Assets (ROA)	Positive
X6[7]	Two-Year Premium Income Yield	Positive
X7	Premium Income Growth Rate	Positive
X8	Liquidity Ratio	Positive

3.2 External Factors

Macroeconomic and Financial Market Environment:

- ΔGDP_t**:** The annual economic growth rate for year
- R_t **:**The benchmark interest rate for year *t*. This study employs the **10-year government bond yield**, which is generally more suitable than generic "rating interest rates" because it serves as the core benchmark for both the discount rate of insurance reserves and the fixed-income investments that constitute the largest portion of insurance fund allocations.

Industry Regulation and Policy Changes: The specific rule changes under the second-phase C-ROSS and the accounting standard reforms systematically affect the industry's solvency profile. Data from Table 1 clearly shows a notable decline in the core solvency adequacy ratio after 2020. This validates that the second-phase C--R-OSS, by raising capital classification requirements, has effectively "squeezed out" inflated capital rate, leading to a more realistic capital assessment.

Corresponding quantitative exogenous variables are introduced:

$$\Delta GDP_t \; R_t$$

A qualitative dummy variable ***IFRS17*** is introduced to represent the new capital constraint requirements under the second-phase C-ROSS framework.

- ***IFRS17*** **= 0:** Before the implementation of the new regulatory requirements.
- ***IFRS17*** **= 1:** After the implementation of the new regulatory requirements.

3.3 Selection of the Dependent Variable

$\boldsymbol{SPI_{i,t}} = C$ore Solvency Adequacy Ratio of Property Insurers

In the context of the full implementation of the second-phase C-ROSS, the **Core Solvency Adequacy Ratio** is selected over the Comprehensive Solvency Adequacy Ratio as the measure of solvency, based primarily on the following three theoretical and practical considerations:

- The essence of consolidated supervision is to identify the **true quality** and **risk-absorption capacity** of capital, not merely to measure its total quantity. **Core capital** is precisely the key focus of consolidated supervision.
- The second-phase C-ROSS aims to optimize insurers' **capital structure** by strengthening capital classification and limiting the proportion of supplementary capital. Changes in the Core Solvency Adequacy Ratio can more sensitively capture the guiding effect of regulatory policies on **capital composition optimization**.
- Supplementary capital (e.g., subordinated debt, capital supplement bonds), while capable of boosting the Comprehensive Solvency Adequacy Ratio in the short term, possesses loss-absorption capability and priority that are subordinate to core capital. Using the Core Solvency measure helps **avoid distortions caused by supplementary capital, ensuring the clarity of research conclusions**.

3.4 Sample Data Acquisition and Processing

Sample Selection

Given the study's focus, a judgmental sampling approach was deemed appropriate. Based on the principles of purposive and representative sampling, 40 property insurance companies were selected. The selection criteria considered company size and industry prominence to ensure the sample's representativeness. To maintain data timeliness, corresponding financial data for the period from 2017 to 2024 were extracted from the official annual reports of these 40 companies.

Data Cleaning

- **Missing Value Treatment**

Missing values in the sample data were addressed. Given the absence of systematic missingness across the 320 observations, with only sporadic missing values for individual financial indicators at very low rates, the **temporal mean imputation method** was employed for completion. This approach was chosen to prevent a loss of estimation efficiency due to sample reduction.

- **Outlier Exclusion**

We apply the Winsorization technique to trim values exceeding the 99th percentile and below the 1st percentile for each variable, replacing them with the respective 99th and 1st percentile values. The effects are shown in Fig1, Fig2 and Table 3.

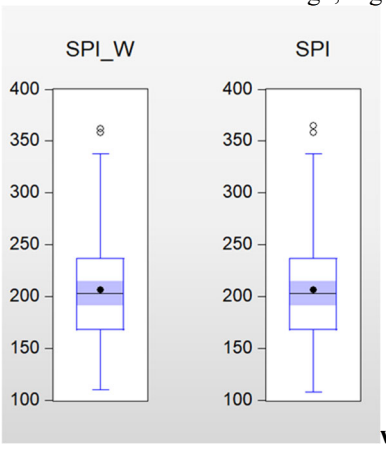

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Fig. 1. SPI Boxplot Graph

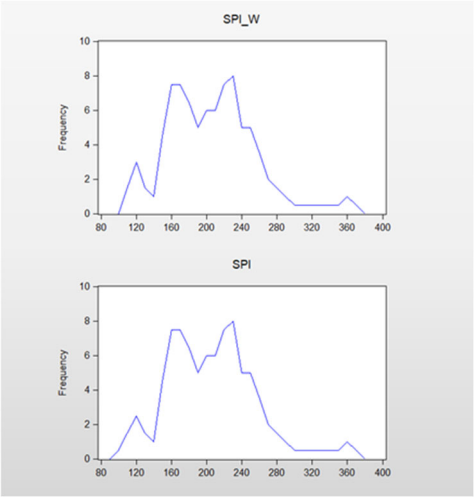

Fig. 2. SPI Histogram Graph

The distribution plots indicate that the Winsorization process effectively mitigated the influence of extreme observations on the variable distributions without altering the overall distribution shape of the solvency indicator. This suggests the data treatment was both **reasonable** and **measured**.

Table 3. The effects of Winsorization on other sample data

Indicator	Statistic	Pre-treatment	Post-treatment (Winsorized)	Interpretation of Change
SPI	min	108.00	114.09	Extreme low value adjusted upward.
	max	365.15	359.29	Extreme high value adjusted downward.
X1	min	0.4215	0.4311	Extreme low value adjusted upward.
	max	0.7485	0.7441	Extreme high value adjusted downward.
X2	min	-0.0125	-0.0125	No change (not an extreme value initially).
	max	0.1986	0.1845	Extreme high value adjusted downward.
X7	min	-0.0912	-0.0306	Extreme negative growth adjusted.
	max	0.2240	0.2149	Extreme positive growth adjusted.

- **Multicollinearity Test**

Table 4. Variance Inflation Factor (VIF) Test Results

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
C **(Constant)**	0.560872	729.5441	NA
X1	0.596146	297.4594	4.503460
X2	36.06060	157.1736	86.89538
X3	105.1975	216.4315	5.093200
X4	2.402984	63.33699	3.172469
X5	143.4781	135.9573	69.71664
X7	0.534770	7.423013	2.030087
X8	2.095965	25.04732	4.722988
GDP	2.830478	12.19836	1.344751
R	112.4157	131.6852	3.511729
IFRS17	0.018584	9.064772	5.665482

The test results indicate strong correlations among certain profitability indicators. Specifically, as shown in Table 4, the Centered VIF values for Return on Assets (X5), the Net Income to Total Revenue Ratio (X2), and the Two-Year Premium Income Yield (X6) significantly exceed 10, suggesting the presence of severe multicollinearity. Given the high degree of economic conceptual overlap between X5 and variables such as the net income ratio, X5 was excluded from subsequent regression analyses to mitigate the distortionary effect of collinearity on parameter estimation. The Centered VIF values for the remaining variables all fall within an acceptable range and thus do not compromise the robustness of the regression results.

4 Model Specification and Estimation

4.1 Model Identification and Effect Specification

The initial modeling strategy aimed to construct a Two-way Fixed Effects model:

$$SPI_{i,t} = \beta_0 + \sum \beta_i x_{i,\ t} + \beta_6 GDP_t + \beta_7 R_t + \beta_8 IFRS17$$

However, the following issues were encountered during the empirical process:

- **Dummy Variable Trap:**

The policy dummy variable *IFRS17* exhibited perfect multicollinearity with the "time fixed effects", leading to a singular covariance matrix.

- **Specification Refinement:**

To accurately capture the policy shock effect of *IFRS17* and resolve the singularity issue, the time fixed effects were dropped in favor of an Individual Fixed Effects model. This specification controls for unobserved time-invariant heterogeneity across insurers while retaining the model's capacity to explain policy changes and macroeconomic fluctuations.

4.2 Model Diagnostics and Selection

- **Preliminary Regression Anomalies:**

Initial estimations exhibited concurrent "high R^2" and "low t-statistic" values—a statistical phenomenon often referred to as "hidden collinearity" or "concurvity"—alongside a low Durbin-Watson statistic. This suggested that in short panels, the variability of some explanatory variables might be overly absorbed by the fixed effects or confounded by serial correlation, indicating potential issues with the initial specification.

- **Hausman Test:**

A Hausman test was conducted to make a statistically grounded choice between the Fixed Effects (FE) and Random Effects (RE) models. The test statistic was significant at the 1% level (p-value = 0.0000), rejecting the null hypothesis and establishing the Fixed Effects model as the consistent estimator for this study.

4.3 Variable Screening and Robust Estimation

- **Variable Elimination:**

The premium income growth rate (X7), which showed an exceedingly high p-value, was excluded to free up degrees of freedom. Simultaneously, it was observed that the benchmark interest rate (R) was highly correlated with GDP and the policy dummy.

Theoretically, in a short panel model, the inclusion of R could compress and duplicate the information conveyed by GDP. Furthermore, given that GDP typically encompasses broader macroeconomic policy signals over identical time horizons in panel models, R was dropped while GDP was retained.

- **Clustered Robust Standard Errors:**

To address the common issues of heteroskedasticity and serial correlation in panel data (evidenced by the low D-W statistic), White (cross-section) covariance correction was applied. This step involves computing clustered robust standard errors, which corrects potential misjudgments of significance from traditional OLS standard errors.

4.4 Empirical Results – The Individual Fixed Effects Panel Data Model

The final estimated model is specified as:

$$SPI_{it} = \beta_0 + \beta_1 LR_{it} + \beta_2 INV_{it} + \beta_3 REIN_{it} + \beta_4 LIQ_{it} + \beta_5 \Delta GDP_t + \beta_6 IFRS17_t + \mu_i + \epsilon_{it}$$

The racial data of very observations are shown as Table 5.

Table 5. Individual Fixed Effects Model Estimation Results

Variable	Abbreviation	Coefficient	Clustered Robust Std. Error	t-Statistic	p-Value
Intercept	C	188.136***	(21.966)	8.565	0.000
Loss Ratio (x1)	LR	-154.121***	(31.942)	-4.825	0.000
Investment Return Rate (x3)	INV	928.414**	(426.172)	2.178	0.033
Reinsurance Ratio (x4)	REIN	304.726**	(145.516)	2.094	0.040
Liquidity Ratio (x8)	LIQ	563.901**	(251.811)	2.239	0.028
GDP Growth Rate	GDP	-134.295***	(37.628)	-3.569	0.001
Regulatory Policy Dummy	IFRS17	-17.627***	(2.462)	-7.159	0.000

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

4.5 Model Testing

- **t-tests and F-test:**

Both individual variable coefficients and the overall model equation passed significance tests at the 95% confidence level, confirming the model's statistical validity.

- **Diagnosis and Treatment of Heteroskedasticity & Serial Correlation:**

Considering the common presence of cross-sectional dependence and serial correlation in panel data, the initial regression's Durbin-Watson statistic slightly below 2 hinted at potential positive serial correlation in the residuals. To ensure valid inference, clustered robust standard errors (White cross-section) were employed uniformly instead of conventional ordinary standard errors. This approach corrects the standard errors without altering coefficient estimates, effectively mitigating interference from heteroskedasticity and autocorrelation on t-statistics and p-values, thereby safeguarding the reliability of the significance conclusions.

- **Preventing Endogeneity and Spurious Regression:**

Prior to formal regression, Fisher-ADF and IPS panel unit root tests were conducted on all variables. The results confirmed that the main variables were stationary in levels or cointegrated. Combined with the support from the Hausman test for the fixed effects model, the constructed model effectively precludes the risk of 'spurious regression' and captures the genuine long-run equilibrium relationships among the variables.

5 Conclusions and Outlook

Against the backdrop of the deepening implementation of the second-phase C-ROSS framework and related regulatory rules, the formation mechanism of insurer solvency is undergoing structural changes. Based on panel data from Chinese property insurance companies for the period 2017–2024, this study conducted a systematic empirical analysis of the main factors influencing the core solvency adequacy ratio, while controlling for firm fixed effects and time effects. The findings indicate that the solvency of property insurers is not determined solely by scale or capital levels but is rather the result of the combined effects of underwriting operations, risk transfer, investment allocation, and the external institutional environment.

At the firm operational level, underwriting profitability exhibits a significantly positive impact on solvency, whereas a higher claims burden substantially erodes capital adequacy. This suggests that within a risk-oriented regulatory framework, relying purely on business expansion is insufficient for sustaining solvency improvement. Underwriting quality and risk-pricing capability remain the foundation for capital soundness[8]. The empirical results for the reinsurance variable reveal that excessive reliance on reinsurance, while providing short-term risk mitigation, may constrain solvency by weakening capital accumulation capacity.

Regarding asset allocation and investment behavior, the investment return rate provides significant support for solvency, highlighting the important role of investment management in insurers' capital formation. Furthermore, the macro interest rate environment exerts a notable influence on solvency, indicating that external financial conditions affect insurers' capital constraints through both asset and liability channels. This finding further underscores the necessity of a macroprudential perspective in insurance supervision.

Additionally, the estimation results for the regulatory regime dummy variable show that the implementation of the second-phase C-ROSS has had a significant impact on

insurer solvency, validating the institutional effect of regulatory adjustments in constraining corporate risk-taking behavior and reshaping capital structures. This result implies that under the new regulatory framework, insurers need to place greater emphasis on the synergy between capital management and risk control, rather than depending on any single business strategy.

The conclusions of this study provide empirical evidence for understanding the formation mechanism of solvency among Chinese property insurers within the new regulatory context. Future research could build upon this work to further examine the heterogeneous responses of different types of insurers to regulatory shocks. Alternatively, employing higher-frequency data and dynamic models could facilitate a deeper analysis of the dynamic relationship between capital adjustments and risk behavior, thereby enriching the research outcomes in this field.

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