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# Risk-based Capital Regime Adoption and Underwriting Performance: Evidence from the Property–Casualty Insurance Industry in Taiwan

**Juei-Hsiang Chen**♦

Department of Risk Management and Insurance, National Chengchi University

**Shih-Chieh Bill Chang**♣

Department of Risk Management and Insurance, National Chengchi University

**Yung-Ming Shiu**♥

Department of Risk Management and Insurance, National Chengchi University

We investigate how risk-based capital (RBC) regime adoption affects the underwriting performance of property–casualty insurers. Our results reveal that, on average, loss ratio has been reduced significantly following the RBC regime adoption. Moreover, the RBC regime adoption increases and reduces the loss ratio on insurers with low and high loss ratios, respectively. We further discover that RBC regime adoption reduces the loss ratio of fire and automobile direct business. These results support the notion that, compared with the minimum capital requirement regime, the RBC regime adoption helps property–casualty insurers to be attentive to underwriting risk.

**Key Words**: Risk-based capital regime adoption; Loss ratio; Property–casualty insurers.

JEL Classifications: G22, G28.

「政策與管理意涵」

因為產險保險人面臨核保結果高度不確定性，所以監理制度性質的轉換造成核保績效何種改變為理論與實務的重要議題。本研究從整體與各險種直接核保業務角度，研究採行風險基礎資本制度對各情況核保績效造成的影響，實證結果證實財產保險業者變得更注意核保風險，提供監理官未來制定新政策與保險人經理人制定核保策略的參考。

♦ Juei-Hsiang Chen is a Ph.D. Candidate in the Department of Risk Management and Insurance, National Chengchi University, No. 64, Sec. 2, Zhinan Rd., Wenshan District, Taipei City 116, Taiwan (R.O.C); 102358501@nccu.edu.tw

♣ Shih-Chieh Bill Chang is a Professor in the Department of Risk Management and Insurance, National Chengchi University, No. 64, Sec. 2, Zhinan Rd., Wenshan District, Taipei City 116, Taiwan (R.O.C); bchang@nccu.edu.tw

♥ Corresponding author. Yung-Ming Shiu is a distinguished Professor in the Department of Risk Management and Insurance, National Chengchi University, No. 64, Sec. 2, Zhinan Rd., Wenshan District, Taipei City 116, Taiwan (R.O.C); yungming@nccu.edu.tw

# 1. Introduction

Capital is a buffer for unexpected losses and thus vital to financial institutions' daily operations. The effects of capital on banks' behaviors have been examined extensively in extant literature.[1] In the context of insurance, certain studies have focused on capital effects on, for example, reinsurance (Shiu, 2011; Shiu and Huang, 2015) and risk.[2] Numerous studies have investigated the influence of capital on various aspects of insurer operations. However, the significant topic on how the adoption of the capital adequacy requirement regime influences insurers' underwriting performance is largely unexplored. Thus, we aim to fill the current gap in the literature by examining how the adoption of solvency requirements for insurers has affected the underwriting performance of property–casualty insurers, also known as non-life insurers. These solvency requirements are referred to as the "risk-based capital" (RBC) regime.

Similar to their life insurer counterparts, property–casualty insurers are required to hold sufficient capital buffer to meet their commitments to their policyholders. Thus, capital is more important for property–casualty insurers than for life insurers because the underwriting risk managed by the former group is more difficult to deal with than that managed by the latter group. The major capital requirement regime for the property-casualty insurance industry in Taiwan is the RBC regime, which is risk-sensitive. This regime came into effect on July 9, 2003. Therefore, insurers are required to continuously maintain a capital adequacy ratio exceeding 200% to prevent supervisory interventions after the RBC regime adoption.

1 Certain examples include Blum (1999), Gambacorta and Mistrulli (2004), and Garel and Petit-Romec (2017).

2 See, for example, Cheng and Weiss (2013), Lin, Lai, and Powers (2014) and Chen, Goh, Kamiya, and Lou (2019).

Before the introduction of the RBC regime, the required paid-up capital of insurers was more than NTD 2 billion.[3] This policy is referred to as the “minimum capital requirement.” However, this policy is not risk-sensitive because all insurers are subject to the same amount of regulatory capital that an insurer must hold. The introduction of the risk-sensitive RBC regime is widely expected to induce senior managers of insurers to gain additional knowledge about the risks of underwriting and investments they have taken when performing their daily business operations and establishing high-level corporate strategies.

In this study, we adopt parametric and non-parametric regression models to examine the effects of the RBC regime adoption on the underwriting performance of property–casualty insurers, proxied by loss ratio. We find that property–casualty insurers, on average, have good underwriting performance (low loss ratio) due to the RBC regime adoption. We also find that the RBC regime adoption increases and decreases the loss ratio for insurers with low and high loss ratios, respectively. Finally, we find that the RBC regime adoption decreases the loss ratio of fire and automobile direct businesses. We aim to advance the extant literature on the effects of capital[4] by shedding light on whether the capital requirements implemented by regulators can effectively change insurers’ behaviors. Accordingly, we directly examine the effects of the adoption of the solvency requirement regime.

To the best of our knowledge, our study is the first to examine the regulatory impact of underwriting performance on insurers’ loss ratio by using the RBC regime adoption. Furthermore, we employ not only parametric models to examine the average effects of the RBC regime adoption on loss ratio but also a non-parametric (nonadditive fixed effect panel quantile regression model) model to examine whether the effects differ across various loss ratio quantiles. Our research

3 As of October 23, 2019, USD 1.00 was equal to TWD 30.6091, based on which the approximate value of NTD 2 billion is USD 65,359,883.

4 Examples include Baranoff et al. (2007), Shiu (2011), Cheng and Weiss (2013), and Shiu and Huang (2015).

also has regulatory implications. Regulators can refer to our empirical results and conclusions to determine whether the original aims of the RBC regime adoption have been achieved. Additionally, they could further develop other risk-sensitive measures for monitoring insurers to improve their solvency and change their behaviors by referring to our study.

## 2. Institutional Background

Figure 1 illustrates the annual aggregate amount of market insurance loss, market insurance income, and market loss ratio from 1995 to 2016.[5] Market insurance income and market insurance loss show an upward trend in our sample period. Before the RBC regime adoption, the average market loss ratio from 1995 to 2002 is 67.26% and significantly reduced to 51.29% from 2003 to 2016 as a result of the shift from the minimum capital requirement regime to the RBC regime.

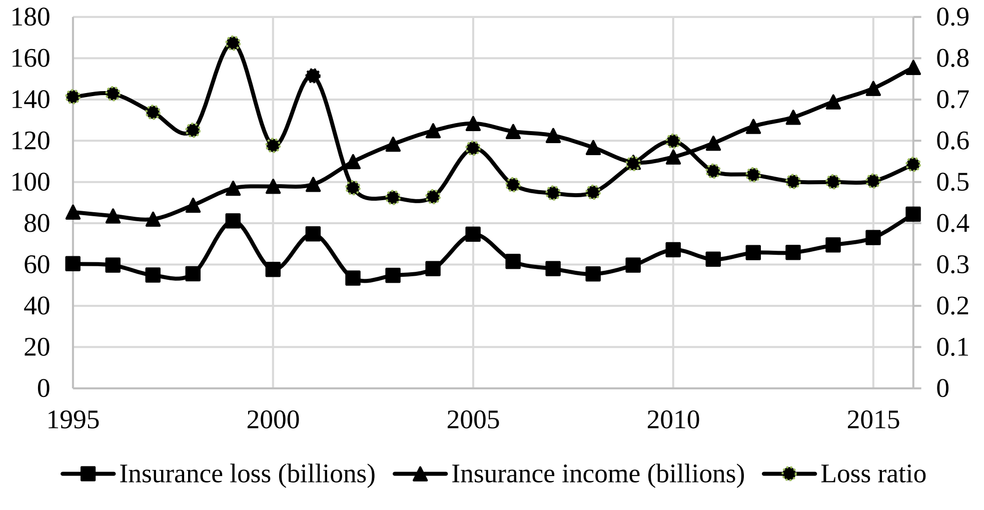


Figure 1 Insurance loss, insurance income, and loss ratio in the Taiwan property–casualty insurance market

5 Data source: Taiwan Insurance Institute website at https://www.tii.org.tw/opencms/. Market loss ratio is defined as market insurance loss divided by market insurance income.

A regulatory capital requirement regime is imposed on firms in the insurance industry in Taiwan, along with rigorous regulatory supervision requirements. Before the RBC regime adoption, the minimum solvency ratio stipulated in the Insurance Act 143 is defined as the ratio of the total admissible assets minus liabilities divided by capital. Additionally, this amount of the total admissible assets minus liabilities should be three times more than the total guarantee deposits. The regulatory authority stipulates the minimum capital requirement urges all property–casualty insurers to hold capital of at least NTD 2 billion. The regulator is also empowered to force insurers to increase their capital holdings within a prescribed period if they violated the RBC requirements.

However, before July 9, 2003, the regulated minimum capital requirement regime did not properly capture the real solvency of insurers in Taiwan. Thus, the regulatory authority announced a new capital adequacy administration regulation on December 20, 2001, to further improve insurers' solvency levels. The RBC regime came into effect on July 9, 2003. The RBC regime adoption represents a shift in regulatory policy from the minimum capital requirement supervision to risk-based supervision. The RBC regime requires insurers to maintain sufficient capital (own funds) determined by the risk that they assumed as a safety net for any unexpected investment and underwriting losses.

Property–casualty insurers' capital adequacy is measured by their RBC ratio, that is, the ratio of owned capital divided by risk capital multiplied by 100% expressed as follows:

$$RBC\ ratio = \frac{Owned\ capital}{Risk\text{−}based\ capital} \times 100\% \tag{1}$$

where owned capital is the equity value of an insurer, and RBC reflects the real risk level undertaken by an insurer. In the context of the property–casualty industry, the risk categories in determining an insurer's RBC include asset, credit, underwriting, asset–liability allocation, and "other" risks. Underwriting risk refers to the risk of underestimating liability for policies issued by an insurer to policyholders and can be divided into reserve risk and premium income risk.[6]

# 3. Literature Review and Hypothesis Development

In our 1998–2016 sample period, the solvency regime on property–casualty insurers in Taiwan has shifted from the minimum capital requirement regime to the RBC regime. Specifically, the solvency regime on the insurance market in Taiwan has moved from dollar-based capital regulation to RBC regulation, with the RBC regime significantly increasing the minimum capital that a property–casualty insurer is required to hold.

Insurers have incentives to adjust their capital and operating behavior to prevent regulatory interventions after the RBC regime adoption (Cheng and Weiss, 2012).[7] In contrast, under the minimum capital requirement regime, insurers have greater incentives to reduce their premiums to attract new customers and relax their underwriting standards to increase their market share (that is, cash flow underwriting). The reason is that regulators would not take any corrective action on insurers if they hold sufficient capital to meet the

6 However, underwriting risk does not include retained claims reserve risk and retained insurance premium income risk in compulsory automobile liability insurance.

7 The RBC regime adoption changes the cost–return trade-off between risk and capital in the insurance industry (Cheng and Weiss, 2013). Insurers incur high regulatory cost if they violate the regulations under both regulatory regimes. Thus, we do not discuss the condition when the amount of capital held by insurers is below the minimum required capital stipulated in the minimum capital requirement and RBC regimes. Property–casualty insurers can underwrite risky policies without any restrictions placed on them by the regulatory authorities when they hold sufficient capital in accordance with the minimum capital requirement regime, that is, above the minimum regulatory required capital. However, they are restricted to risk capital charges under the RBC regime, denoting that the minimum regulatory required capital increases with the increase in risk they take. Therefore, they cannot underwrite numerous risky policies without any restrictions under the RBC regime. The duration of insurance products in the property–casualty insurance industry is relatively short term. Similarly, their investment duration is also short term based on the asset–liability matching principle. As a result, insurers could not increase their investment performance by investing and thus cannot increase their RBC ratios by increasing their investment returns. Therefore, these insurers are concerned about their underwriting risk and take measures to effectively manage it.

minimum capital requirement standard. However, under the RBC regime, insurers are required to maintain their RBC ratio above the regulatory-required RBC ratio. Thus, they must set a high underwriting standard and put great effort into loss prevention and mitigation.

We argue that, under the RBC regime, insurers have greater incentives to put a great effort into screening policyholders, risk classification, loss prevention activities, and loss mitigation activities than under the minimum capital requirement regime because the RBC regime has higher regulatory costs (Lin et al., 2014). Under the RBC regime, regulators monitor insurers' investment and underwriting activities to maintain an appropriate level of insurers' RBC ratio. However, under the minimum capital requirement regime, regulators only concern about whether insurers are holding sufficient capital. Moreover, information asymmetry can be mitigated as a result of the RBC regime adoption. Specifically, insurers undertake steps to mitigate adverse selection by putting great effort into screening policyholder characteristics and risk classification. They also take measures to mitigate moral hazard by reducing insurance fraud to reduce claim expenses. Furthermore, policyholder and consumer awareness of insolvency incentivize insurers to raise capital for excess risk-taking to avoid regulatory actions. Cummins and Sommer (1996) find that insurers are likely to limit their risk-taking for the safety of policyholders.

In addition, managers devote their attention, time, abilities, and effort to the underwriting and investment activities of their insurers. Based on human capital theory, great human capital can be transformed into greater productivity (Chen et al., 2018). Hence, they also allocate their resources in human capital investment in their insurers. As a result, they hold high capital and capital buffers to maintain their reputation and job security (Cheng and Weiss, 2013). Agency theory also contends that the separation of management and ownership allows managers of insurers to take less risk because they do not share residual profits with the owners (Lin et al., 2014). Therefore, managers have strong incentives to reduce underwriting risk in the post-RBC regime adoption period. Transaction cost economics also posits that financial institutions limit their product risks to avoid high financing costs as debt financing costs increase if they sell risky products (Williamson, 1988). Based on the above discussions, we propose our first hypothesis as follows:

Hypothesis 1: *The loss ratio after the RBC regime adoption is lower than that before the RBC regime adoption.*

However, the effects of the RBC regime adoption on loss ratio are not the same across different types of insurers. Shrieves and Dahl (1992) find that the magnitude of the RBC regime on banks' risk-taking depends on the distance between banks' RBC level and standard RBC level. Jacques and Nigro (1997) note that weak and healthy banks react differently to various RBC regulatory pressures, suggesting that capital level and regulatory pressure may not be linearly correlated. In addition, Cheng and Weiss (2013) note that the target capital structure of undercapitalized and marginally capitalized insurers is likely to be affected by the RBC regime adoption. Lin et al. (2014) subsequently construct a theoretical model that predicts varying capital–risk relationships across different regulatory pressure regimes.

Regulatory costs differ across various characteristics of insurers and reduce with an increase in the distance of actual capital minus minimum required capital. Lin et al. (2014) suggest that the RBC regime may impose certain regulatory requirements that can result in different regulatory costs incurred, depending on the capital ratio level of an insurer; the higher the capital ratio, the lower is the incentive for insurers to take measures to increase their RBC ratio essentially because the probability of such insurers provoking disciplinary action by the regulators is low.

The RBC regime adoption should improve the solvency position of marginally capitalized insurers as they are faced with high regulatory costs (Cheng and Weiss, 2013). Furthermore, insurers with a high loss ratio exhibit lower underwriting performance than insurers with a low loss ratio (Chen, Chen, and Lin, 2004). Additionally, insurers with a higher loss ratio are also charged with a higher risk capital than those with a lower loss ratio. Poor underwriting performance deteriorates an insurer's own capital. Thus, insurers with a high loss ratio face high-risk capital charges and reductions in their capital, resulting in a low RBC ratio under the RBC regime. Therefore, such insurers with a higher loss ratio have a lower RBC ratio and are faced with higher regulatory costs compared with insurers with a lower loss ratio. Specifically, insurers with a higher loss ratio have greater incentives to take measures to reduce their underwriting risk under the RBC regime than insurers with a lower loss ratio.

Insurers with a low loss ratio adopt less risky underwriting strategies and are charged with a low-risk capital *ex ante* under the RBC regime. Their capital is not severely deteriorated *ex post*. Therefore, the capital buffer of insurers with a lower loss ratio is larger than that of insurers with a higher loss ratio. However, holding more capital buffer than the appropriate level increases opportunity cost because insurers could use these funds to expand their underwriting business or investment. Based on transaction cost economics (Williamson, 1988), insurers sell risky products because they have less financing demand. Insurers with a low loss ratio adopt risky underwriting strategies to reduce the opportunity cost of holding additional capital after the RBC regime adoption, resulting in an increased loss ratio. The above discussions lead us to our second hypothesis as follows:

Hypothesis 2: *The RBC regime adoption increases and decreases the loss ratio of insurers with low and high loss ratios, respectively.*

# 4. Variables, Data, and Methodology

## 4.1 Variables

### *4.1.1 Dependent variable: Loss ratio (LR)*

Loss ratio is a commonly adopted measure of underwriting risk (Kader, Adams and Mouratidis, 2010) and underwriting performance (Adams and Jiang, 2016) within the non-life insurance sector. An insurer's underwriting experience is poor if the insurer has a high loss ratio. We define loss ratio (*LR*) as the ratio of gross insurance losses divided by premium income (Shiu and Hsiao, 2014).

### *4.1.2 Independent Variables*

*a. Risk-based capital regime adoption* (*ImpRBC*)

Given that the sample period for this study starts from 1996 to 2016, *ImpRBC* is an indicator variable that equals 1 if the observation is between 2003 and 2016 and 0 otherwise.

*b. Pricing deregulation* (*PDereg*)

Taiwan adopted the pricing deregulation in April 2009 (Peng et al., 2016), with the insurance market consequently being transformed from an environment of stringent premium regulation to a competitive one. This transformation increases the likelihood of insurers to engage in a price war after observing the premium rates offered by their competitors. As a result, insurers' premium incomes decline, increasing the loss ratio or decreasing insurance price. Therefore, we expect that pricing deregulation increases the loss ratio. *PDereg* is an indicator variable that equals 1 if the observation is between 2009 and 2016 and 0 otherwise.

*c. 1- and 2-year lagged loss ratio* (*LR*-1 and *LR*-2)

Underwriting cycles emerge in the property–casualty insurance industry and are characterized by periods of high profitability followed by periods of low profitability (Boyer and Owadally, 2015). The second-order autoregressive process is a statistical model that provides a simplified description of insurers' underwriting behavior (Venezian, 1985; Cummins and Outreville, 1987). Therefore, we include 1- and 2-year lagged loss ratio variables and expect *LR*-1 (*LR*-2) to positively (negatively) correlated with the current year loss ratio.

*d. Firm size* (*Size*)

Borde, Chambliss, and Madura (1994) and Chen and Wong (2004) indicate that property–casualty insurers may relax their underwriting standards to obtain investment funds (cash flow underwriting). Hardwick, Adams, and Zou (2011) also indicate that economies of scale and scope exist in the underwriting expense of large insurers, suggesting that large firms have great underwriting capacity to tolerate high loss ratio while maintaining a combined ratio at the same level. However, large firms are likely to engage in enterprise risk management (Hoyt and Liebenberg, 2011) and allocate resources in loss mitigation activities. Therefore, we do not expect the firm size to affect the loss ratio. *Size* is defined in this study as the natural logarithm of total assets.

*e. Insurance leverage* (*InsLev*)

The higher the insurance leverage, the more aggressive are the strategies taken by property–casualty insurers. This condition may indicate that these insurers reduce their underwriting standards to obtain additional business. *InsLev* is defined in this study as the ratio of total net premiums written to policyholder surplus (Yan, 2013). We expect this variable to positively correlate with the loss ratio.

*f. Line-of-business concentration* (*LoBCon*)

Insurers with various concentrated businesses in terms of their business mix can specialize in their specific areas and thus have superior underwriting experience. However, insurers with high business concentration tend to take high underwriting risk. Thus, line-of-business concentration is not expected to affect the loss ratio. Line-of-business concentration (*LoBCon*) is defined in this study as the Herfindahl index of premiums written in the insurer's line of business.

*g. Investment yield* (*InvY*)

Insurers with high investment profitability may choose to relax their underwriting standards to collect additional premium income for investment. Therefore, we expect investment performance (*InvY*) to positively associate with the loss ratio. *InvY* is defined in this study as the ratio of investment income divided by total invested assets (Garver and Pottier, 2005).

*h. Firm age* (*Age*)

Ferguson, Deephouse, and Ferguson (2000) note that property–casualty insurers take a long time to build a good customer base and accumulate underwriting capacity. Anderson and Formisano (1988) also argue that insurers with a long history of operations have accumulated more underwriting experience and, thus, have a greater ability to control loss ratio than those with a limited history of operations only. Therefore, we expect a lower (higher) loss ratio for insurers with many (fewer) years of operations. *Age* is defined in this study as the natural logarithm of accumulated years since the firm was founded.

*i. Financial conglomerate* (*FinCon*)

Financial conglomerate (*FinCon*) includes financial holding companies and is a dummy variable that equals 1 if the insurer is a financial holding company subsidiary or member and 0 otherwise. The financial holding company or financial conglomerate often provides a high business priority to its subsidiaries and members and monitors their underwriting business to protect its reputation when the capital adequacy ratio of its subsidiaries and members is lower than the regulatory requirement. Thus, we expect a lower loss ratio for insurers affiliated with a financial conglomerate than for those without such an affiliation.

*j. Listed*

The extent of monitoring insurers through the capital market is higher for listed insurers than for private insurers particularly because listed insurers are monitored by shareholders and analysts unlike private firms (Lee and Lee, 2012).

This condition suggests that listed insurers put greater effort into their underwriting and claim-handling activities compared with private insurers, including screening policyholders and actively preventing moral hazard. Furthermore, listed insurers have financial market access to acquire needed capital and, thus, have high underwriting capacity, enabling them to tolerate high underwriting risks. Therefore, listing is not expected to affect the loss ratio. *Listed* is an indicator variable that equals 1 for listed firms and 0 otherwise.

*k. Reinsurance* (*Reins*)

Insurers transfer part of their business to reinsurers for risk diversification (Ferguson et al., 2000) and real service (Anand et al., 2020). Specifically, based on the real service hypothesis, reinsurers provide expertise and specialized knowledge to insurers to improve their underwriting performance. Therefore, *Reins* is expected to negatively correlate with the loss ratio. *Reins* is measured in this study as the ratio of reinsurance ceded to gross premiums written.[8]

*l. Growth in the gross domestic product* (*GinGDP*) *and stock market index returns* (*SMRet*)

Considering that insurance products are normal goods, the demand for insurance increases with the overall economic improvement. High insurance premium reduces the loss ratio. However, considerable insurance coverage induces moral hazard problems, significantly increasing insurance losses because policyholders may put less effort into preventing adverse events or mitigating the extent of any losses. Therefore, either growth in gross domestic product (GDP) or stock market index return is not expected to affect the loss ratio. *GinGDP* is defined in this study as the annual GDP growth rate, whereas *SMRet* is the annual growth rate in a stock market index.

*m. Inflation rate* (*Inf*)

8 This approach is in line with several related studies, including Adams (1996), Cole and McCullough (2006), Garven and Lamm-Tennant, (2003) and Shiu (2011).

The direct effect of an increase in inflation rate is the resultant costs of claims after the policies are sold, whereas increases in the price of other goods are in direct competition with insurance policies for household expenditure. However, Grace and Hotchkiss (1995) suggest that the direct effect of the cost of claims dominates the competing goods effect because the short-run demand for insurance is price inelastic. Therefore, inflation rate is expected to positively associate with the loss ratio. *Inf* is measured in this study as the annual change in a consumer price index.

*n. Growth in interest rates* (*GinIR*)

Based on the insurance capital asset pricing (ICAPM), discounted cash flow (DCF), and option pricing models, insurance premium negatively correlates with interest rate (Haley, 1993). Furthermore, interest rate changes are also linked to insurance price changes (Doherty and Kang, 1988) because interest rate plays a role of discount rate in calculating insurance premium. The higher the interest rate growth, the higher is the interest rate, the lower is the present value of the expected loss, and the lower is the insurance premium. However, *GinIR* is expected to positively correlate with loss ratio because it is the inverse measure of insurance price. *GinIR* is defined in this study as the annual growth rate in interest rate.

## 4.2 Data

The data used in this study are obtained from two main sources. The data of insurers' characteristics and underwriting are obtained from the yearbooks and annual financial reports provided by Taiwan Insurance Institute, whereas macroeconomic data, including GDP growth, inflation rate, interest rate growth, and market index return data, are obtained from Taiwan Economic Journal. Our sample comprises 18 insurance firms from 1998 to 2016, providing 276 firm-year observations.[9] Table 1 provides the definitions of all variables used in this study.

9 It is noteworthy that our original sample period is from 1996 to 2016. However, the resulting sample period covers from 1998 to 2016 due to the use of loss ratio variables lagged by up to 2 years.

Table 1 Variable definitions

| Variables | Definitions |
|---|---|
| *LR* | Loss ratio: the ratio of insurance loss divided by insurance income |
| *LR*-1 | 1-year lagged loss ratio |
| *LR*-2 | 2-year lagged loss ratio |
| *ImpRBC* | RBC regime implementation: a dummy variable that equals 1 if the period is from 2003 to 2016 and 0 otherwise |
| *PDereg* | Pricing deregulation: a dummy variable that equals 1 if the observation is between 2009 and 2016 and 0 otherwise |
| *Size* | Firm size: the natural logarithm of total assets |
| *InsLev* | Insurance leverage: the ratio of total net premium written to policyholder surplus |
| *LoBCon* | Line-of-business concentration: measured by the Herfindahl index of line-of-business concentration using premiums written by the insurer in a particular line of business |
| *InvY* | Investment yield: the ratio of net investment income divided by total invested assets |
| *Age* | Firm age: the natural logarithm of accumulated years since the firm's foundation |
| *FinCon* | Financial conglomerates: a dummy variable that equals 1 if the insurer is a financial holding company subsidiary or member and 0 otherwise |
| *Listed* | A dummy variable that equals 1 for listed firms and 0 otherwise |
| *Reins* | Reinsurance: measured as the ratio of reinsurance ceded to gross premiums written |
| *Liq* | Liquidity: defined as the ratio of cash and cash equivalent to total assets |
| *GinGDP* | Growth in gross domestic product (GDP): measured as the annual GDP growth rate |
| *Inf* | Inflation rate: measured by the annual growth rate in a consumer price index |
| *GinIR* | Growth in interest rate: measured as the annual growth in interest rate |
| *SMRet* | Stock market index return: measured as the annual growth rate in a stock market index |

## 4.3 Methodology

We examine the structural change of loss ratio resulting from the RBC regime adoption and therefore employ the following regression specification:

$$LR_{i,t} = \alpha_i + \beta_1 \cdot ImpRBC_t + \beta_2' \cdot CV_{i,t} + \varepsilon_{2,i,t} \quad (2)$$

where $LR_{i,t}$ denotes the loss ratio of firm $i$ at time $t$; $ImpRBC$ is a dummy variable indicating the period before or after the RBC regime adoption;[10] $CV_{i,t}$ refers to control variables; $\beta_2'$ refers to the effects of control variables on loss ratio; $\alpha_i$ is an individual fixed effect; $\beta_1$ captures the average difference in loss ratio before and after the RBC regime adoption; and $\varepsilon_{2,i,t}$ is the residual term of Equation (2).

The models used in this study include fixed effects, tobit, generalized least squares (GLS), and random effects tobit (RETobit) models. We use the GLS model because it accounts for heteroscedasticity in error terms and adopt Wooldridge's (2016) robust standard deviations.[11] Our specified model is a dynamic panel data model because the lagged dependent variables *LR-1* and *LR-2* are included as explanatory variables. However, these variables may be associated with error terms, which may bias the results. Thus, we estimate the effects of the RBC regime adoption on loss ratio using the difference generalized method of moments (GMM) model (Arellano and Bond, 1991) and system GMM model (Blundell and Bond, 1998). These models are appropriate for dynamic panel specifications to mitigate bias concerns.

Our results are robust to many aspects of our model specification. However, the parametric models can capture the average effects only. Thus, we need to

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10 We are grateful to an anonymous referee for pointing out that the use of a dummy variable to test policy effect is associated with several disadvantages and suggesting to analyze average treatment effect. However, the RBC regime adoption affects all insurers. Thus, we do not establish a control group that is not affected by the policy change in our setting. This approach makes the estimation of average treatment effect infeasible (Woolridge, 2016). We agree that the use of a dummy variable to test the policy effect is associated with several disadvantages. Therefore, we would like to caution readers about the possible disadvantages associated with the use of a dummy variable in this setting. For instance, this approach ignores the effects from specific risk charge on underwriting performance. Moreover, the approach could not capture the effects from factors accompanied with the regulatory advancement. The RBC regulations in the past may have numerous modifications. We are unable to analyze the average treatment effect due to insufficient availability of data on a control group. Nevertheless, the availability of such data may enable future research to explore in detail how the RBC regime adoption may affect insurers' underwriting performance.

11 The advantage of fixed effects model is that it can control for unobserved and time-invariant differences across insurers. The tobit model captures the correlation between the non-negative dependent and independent variables (Tobin, 1958). The random effects model assumes that unobservable effects are not associated with each independent variable (Wooldridge, 2016).

further address the tail information of loss ratio and illustrate how the RBC regime adoption has affected different loss ratio quantiles. The effects of the RBC regime adoption on loss ratio are state-dependent; thus, the influences on loss ratio vary among different quantiles. The quantile regression enables us to examine the correlation between the RBC regime adoption and loss ratio for any specific quantile. As a result, the estimates using the quantile regression model are more efficient and robust compared with those using the OLS regression model.

Our regression specification is an autoregressive dynamic panel data model because our explanatory variables include lagged dependent variables. Dynamic panel data bias may exist when lagged dependent variables are associated with errors. Therefore, we use a nonadditive fixed effect panel quantile regression model to estimate the effects of *ImpRBC* on loss ratio.[12] The conditional quantile of the dependent variable $y_{i,t}$ given a vector of regressors $x_{i,t}$ can be presented as follows:

$$y_{i,t}\left(\tau_k | \alpha_i, x_{i,t}\right) = \alpha_i + x_{i,t}^T \cdot \beta(\tau_k) \tag{3}$$

where $\alpha_i$ represents the unobserved individual heterogeneity; τ denotes the τth quantile of loss ratio τ∈(0,1); and β is the vector of parameters to be estimated, representing the association between the independent variable and τth conditional quantile of loss ratio.

Following Powell (2016), we employ a quantile regression estimator for panel data with nonadditive fixed effects to estimate the effects of explanatory variables on the dependent variable. Baker's (2016) user-written qregpd command in Stata 12.0 is used. In addition, we use numerical optimization by conducting the adaptive Markov chain Monte Carlo procedure.[13]

12 The nonadditive fixed effects quantile regression model estimates by using expectation rather than by estimating fixed effects (Powell, 2016). When independent variables contain lagged year dependent variables, it does not generate endogeneity problem between current year and lagged year dependent variables.

13 The value of "draw," "burn," and "arate" must be specified to implement numerical optimization. Following Chen and Shiu (2020), we specify that "draw," "burn," and "arate" are 1000, 100 and 0.5, respectively.

# 5. Empirical Results

## 5.1 Univariate Analysis

Table 2 presents the descriptive statistics of the variables used in our study, showing that *LR* and *ImpRBC* have a mean and standard deviation of 0.502 and 0.170 and 0.712 and 0.453, respectively.

Table 2 Descriptive statistics

| Variables | Mean | S.D. | Min | Median | Max | No. of obs. |
|---|---|---|---|---|---|---|
| *LR* | 0.50081 | 0.16977 | 0.11719 | 0.47617 | 1.48204 | 276 |
| *LR*-1 | 0.50621 | 0.18698 | 0.11719 | 0.47636 | 1.83644 | 276 |
| *LR*-2 | 0.51658 | 0.19332 | 0.11719 | 0.48474 | 1.83644 | 276 |
| *ImpRBC* | 0.71376 | 0.45282 | 0.00000 | 1.00000 | 1.00000 | 276 |
| *PDereg* | 0.40579 | 0.49193 | 0.00000 | 0.00000 | 1.00000 | 276 |
| *Size* | 23.20128 | 0.70599 | 21.16910 | 23.20165 | 25.13940 | 276 |
| *InsLev* | 1.08308 | 2.07772 | −29.14460 | 1.06914 | 9.10877 | 276 |
| *LoBCon* | 0.34360 | 0.10818 | 0.15524 | 0.34128 | 0.85572 | 276 |
| *InvY* | 0.05170 | 0.03993 | −0.01032 | 0.04053 | 0.18734 | 276 |
| *Age* | 3.58445 | 0.70147 | 1.09861 | 3.78419 | 4.43082 | 276 |
| *FinCon* | 0.26449 | 0.44186 | 0.00000 | 0.00000 | 1.00000 | 276 |
| *Listed* | 0.26811 | 0.44378 | 0.00000 | 0.00000 | 1.00000 | 276 |
| *Reins* | 0.43896 | 0.13176 | 0.18449 | 0.44694 | 0.79907 | 276 |
| *GinGDP* | 0.04014 | 0.03128 | −0.01910 | 0.04536 | 0.08931 | 276 |
| *Inf* | 0.00872 | 0.02123 | −0.03710 | 0.00780 | 0.05990 | 276 |
| *GinIR* | −0.07662 | 0.26982 | −0.53125 | 0.00000 | 0.41243 | 276 |
| *SMRet* | 0.04540 | 0.27936 | −0.46026 | 0.08724 | 0.78343 | 276 |

The Pearson correlation coefficient matrix in Table 3 reveals a negative correlation between *ImpRBC* and *LR*, with significance at the 1% level. Thus, preliminary supporting hypothesis 1 and indicating a lower loss ratio after the RBC regime adoption compared with that before the RBC regime adoption.

Table 3 Pearson correlation matrix

Note: ***, **, and * indicates statistical significance at the 1%, 5%, and 10% level, respectively.

| Variables | *LR* | *ImpRBC* | *PDereg* | *LR*-1 | *LR*-2 | *Size* | *InsLev* | *LoBCon* |
|---|---|---|---|---|---|---|---|---|
| *ImpRBC* | −0.465*** | | | | | | | |
| *PDereg* | −0.185*** | 0.523*** | | | | | | |
| *LR*-1 | 0.428*** | −0.504*** | −0.230*** | | | | | |
| *LR*-2 | 0.321*** | −0.371*** | −0.269*** | 0.375*** | | | | |
| *Size* | −0.424*** | 0.271*** | 0.320*** | −0.329*** | −0.345*** | | | |
| *InsLev* | 0.011 | −0.040 | 0.057 | 0.030 | 0.083 | 0.006 | | |
| *LoBCon* | 0.179*** | −0.269*** | −0.097 | 0.137** | 0.072 | −0.275*** | 0.230*** | |
| *InvY* | 0.164*** | −0.306*** | −0.288*** | 0.138** | 0.104* | −0.014 | −0.090 | −0.262*** |
| *Age* | −0.084 | 0.089 | 0.066 | −0.085 | −0.053 | 0.316*** | −0.163*** | −0.534*** |
| *FinCon* | −0.202*** | 0.289*** | 0.190*** | −0.195*** | −0.201*** | 0.311*** | 0.035 | −0.110* |
| *Listed* | 0.090 | 0.076 | 0.033 | 0.075 | 0.069 | 0.030 | 0.040 | 0.018 |
| *Reins* | 0.236*** | −0.458*** | −0.543*** | 0.262*** | 0.350*** | −0.275*** | −0.112* | −0.267*** |
| *GinGDP* | 0.209*** | −0.163*** | −0.297*** | −0.014 | 0.163*** | −0.082 | −0.074 | 0.071 |
| *Inf* | 0.049 | −0.209*** | 0.036 | 0.150** | −0.089 | 0.003 | 0.021 | 0.050 |
| *GinIR* | −0.117* | 0.377*** | 0.111* | −0.135** | −0.313*** | 0.102* | −0.071 | −0.085 |
| *SMRet* | −0.195*** | 0.102* | 0.010 | 0.081 | −0.224*** | 0.032 | −0.005 | −0.038 |

| Variables | *InvY* | *Age* | *FinCon* | *Listed* | *Reins* | *GinGDP* | *Inf* | *GinIR* |
|---|---|---|---|---|---|---|---|---|
| *Age* | 0.221*** | | | | | | | |
| *FinCon* | 0.118* | −0.205*** | | | | | | |
| *Listed* | −0.064 | 0.225*** | −0.363*** | | | | | |
| *Reins* | 0.345*** | 0.288*** | −0.269*** | −0.045 | | | | |
| *GinGDP* | 0.015 | 0.029 | −0.082 | −0.056 | 0.164*** | | | |
| *Inf* | 0.010 | 0.001 | −0.024 | −0.015 | −0.052 | −0.173*** | | |
| *GinIR* | −0.124** | 0.045 | 0.114* | −0.004 | −0.179*** | 0.006 | −0.115* | |
| *SMRet* | −0.060 | 0.015 | 0.028 | −0.011 | −0.056 | −0.148** | −0.204*** | 0.594*** |

Table 4 reports the average loss ratios of 18 property–casualty insurers in the pre- and post-RBC regime adoption periods. Fifteen of these insurers have average loss ratio data in the pre- and post-RBC regime adoption periods, whereas only two and one have average loss ratio data before and after the RBC regime adoption, respectively.[14]

Table 4 Loss ratios of individual insurers in the pre- and post-RBC regime adoption periods

Note: ***, **, and * indicates statistical significance at the 1%, 5%, and 10% level, respectively.

| Company name | Average loss ratio | | T-test |
|---|---|---|---|
| | Pre-RBC (a) | Post-RBC (b) | (a) − (b) |
| Taiwan Fire & Marine Insurance Co. Ltd. | 0.6450 | 0.4333 | −2.7561*** |
| Chung Kuo Insurance Co., Ltd. | 0.5552 | 0.4435 | −2.0341* |
| Fubon Insurance Co., Ltd. | 0.4600 | 0.2934 | −3.9607*** |
| Taian Insurance Co., Ltd. | 0.5762 | 0.4282 | −1.9453* |
| MSIG Mingtai Insurance Co., Ltd. | 0.6239 | 0.4522 | −5.9688*** |
| Zurich Insurance (Taiwan) Ltd. | 0.5326 | 0.4297 | −2.5397** |
| AIG Taiwan Insurance Co., Ltd. | 0.7729 | 0.3825 | −2.7703** |
| The First Insurance Co., Ltd. | 0.6214 | 0.5095 | −2.8523** |
| Union Insurance Co., Ltd. | 0.6436 | 0.5650 | −1.2310 |
| Sinkong Insurance Co., Ltd. | 0.5977 | 0.4455 | −2.7810** |
| South China Insurance Co. | 0.5602 | 0.4647 | −3.6026*** |
| Cathay Century Insurance Co. Ltd. | 0.4807 | 0.3989 | −2.2115** |
| Tokio Marine Newa Insurance Co., Ltd. | 0.5503 | 0.5156 | −0.8760 |
| TLG Insurance Co., Ltd. | N/A | 0.5384 | N/A |
| The Tai Ping Insurance Co., Ltd. | 0.8554 | 0.5649 | −1.6716 |
| Kuo Hua Insurance Co., Ltd. | 0.6904 | 0.6810 | N/A |
| Allianz President General Insurance Co. Ltd. | 0.6824 | N/A | N/A |
| China Mariners. | 0.7166 | N/A | N/A |

14 We use a t-test to examine whether significant differences exist between the loss ratios in the pre- and post-RBC regime adoption periods on individual insurers. The results reveal that loss ratios after the RBC regime adoption are significantly lower than loss ratios before the RBC regime adoption, except for Union Insurance Corp. Ltd., Tokio Marine Newa Insurance Corp. Ltd., and The Tai Ping Insurance Corp. Ltd. These results provide preliminary evidence for hypothesis 1 from the viewpoint of individual insurers' loss ratio.

## 5.2 Multivariate Analysis

This section begins by calculating the variance inflation factor (VIF) values of the independent variables to determine whether potential multicollinearity exists. The results reveal that the VIF values range from 1.10 to 2.97, which is well below the "rule of thumb" cutoff of 10 (Kennedy, 1998). Therefore, we can conclude that our study has no serious multicollinearity problem.

Table 5 presents the results estimated by the fixed effects, tobit, GLS, RETobit, difference GMM, and system GMM models. The results indicate an adjusted $R^2$ value is 0.53884. The F-statistics and $\chi^2$ statistics in all the models are significant at the 1% level, thereby suggesting that at least one estimator is significantly different from zero in all three equations. The numbers of instrumental variables used in the difference GMM and system GMM models are 199 and 218, respectively. In addition, the Hansen J-statistics values are 166.163 and 176.102, both insignificant at the 10% level. Therefore, the instrumental variables are not associated with errors and thus appropriate. Overall, our model setting is appropriate.

The results show that *ImpRBC* is negatively associated with *LR*, with 1% significance. Therefore, the loss ratio is lower in the post-RBC regime adoption period than that in the pre-RBC regime adoption period, which is consistent with hypothesis 1.[15] This finding is also consistent with Shiu and Huang (2015), who note that reinsurance usage after the RBC regime adoption is significantly lower than that before the RBC regime adoption. Their finding on reinsurance usage may

15 In this study, 18 property–casualty insurers, that is, 18 cross-section units, are included, and the estimation period covers from 1996 to 2016, with 21 time points. Wooldridge (2016) indicates that using the first-difference model could solve the concern that the number of cross-section units is less than the number of time points and obtain a consistent estimator by applying the central limit theorem. Therefore, we also employ the first-difference model to estimate the RBC regime adoption effects on loss ratio and find that *ImpRBC* negatively associates with LR, with 1% significance. This finding also supports the hypothesis 1.

well be explained by the reduction in loss ratio. Our results are also consistent with the finding of Deli and Hasan (2017), who argue that banks are encouraged to reduce the weighting of their risky assets due to the adoption of increased capital requirements to meet regulatory requirements.

The results of the control variables show that *PDereg* positively correlates with *LR*, with at least 10% significance. Therefore, pricing deregulation significantly reduces insurance premiums and, thus, increases the loss ratio. The estimations results of all models reveal positive correlations between *LR*-1 and current *LR*, with at least 1% significance. Thus, the loss ratio can be explained by prior underwriting experience. In addition, *LR*-2 is significant and negatively correlates with current *LR* under the system GMM model. This result suggests that the underwriting cycle exists in the Taiwanese property–casualty insurance market. The estimation results of the tobit, GLS, and RETobit models reveal negative correlations between *Size* and *LR*, with 1% significance. Therefore, large firms tend to invest substantial resources in loss mitigation activities. *Listed* is found to have a positive association with *LR*, with 1% significance. Thus, listed firms are monitored by shareholders and analysts; thus, insurers increase their underwriting capacity.

Contrary to our prior expectation, *Inf* negatively correlates with *LR*. Thus, the competing goods effect may dominate the direct effect of the costs of claims. *GinIR* negatively correlates with *LR*, consistent with the ICAPM and DCF model. *SMRet* negatively correlates with *LR*, suggesting that a good economic environment induces policyholders to increase their insurance demand, reducing the loss ratio.

Next, a nonadditive fixed effect panel quantile regression model is used to examine whether the effects of the RBC regime adoption on loss ratio differ across varying loss ratio quantiles. Table 6 reports the main results of the effects of the RBC regime adoption on loss ratio across different loss ratio quantiles.

Table 5 Effects of the RBC regime adoption on loss ratio by fixed effects, tobit, generalized least squares, random effect tobit, difference GMM, and system GMM parametric models

Note: ***, **, and * indicates statistical significance at the 1%, 5%, and 10% level, respectively.

| Models | Fixed effects | | Tobit | | GLS | | RETobit | | GMM-difference | | GMM-system | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variables | Coeff. | S.E. | Coeff. | S.E. | Coeff. | S.E. | Coeff. | S.E. | Coeff. | S.E. | Coeff. | S.E. |
| Constant | 0.657 | 0.802 | 3.162*** | 0.243 | 3.162*** | 0.406 | 3.214*** | 0.454 | 1.731 | 1.076 | 1.510** | 0.705 |
| *ImpRBC* | −1.292*** | 0.201 | −1.341*** | 0.193 | −1.341*** | 0.307 | −1.314*** | 0.301 | −1.310*** | 0.352 | −0.877*** | 0.286 |
| *PDereg* | 1.390*** | 0.205 | 0.531*** | 0.186 | 0.531** | 0.267 | 0.505* | 0.286 | 1.418*** | 0.392 | 0.976*** | 0.324 |
| *LR*-1 | 0.192*** | 0.057 | 0.290*** | 0.069 | 0.290*** | 0.046 | 0.265*** | 0.048 | 0.207*** | 0.056 | 0.201*** | 0.046 |
| *LR*-2 | −0.088 | 0.101 | 0.002 | 0.056 | 0.002 | 0.045 | −0.026 | 0.048 | −0.079 | 0.051 | −0.098** | 0.042 |
| *Size* | −0.013 | 0.037 | −0.067*** | 0.011 | −0.067*** | 0.011 | −0.067*** | 0.014 | −0.073 | 0.051 | −0.048 | 0.033 |
| *InsLev* | 0.004 | 0.003 | 0.001 | 0.002 | 0.001 | 0.003 | 0.003 | 0.003 | 0.004 | 0.004 | 0.004 | 0.004 |
| *LoBCon* | −0.301 | 0.196 | 0.009 | 0.104 | 0.009 | 0.081 | −0.074 | 0.111 | −0.168 | 0.198 | −0.120 | 0.184 |
| *InvY* | −0.221 | 0.438 | −0.051 | 0.177 | −0.051 | 0.189 | −0.146 | 0.229 | −0.225 | 0.366 | −0.216 | 0.333 |
| *Age* | −0.033 | 0.074 | 0.017 | 0.012 | 0.017 | 0.013 | 0.013 | 0.016 | 0.035 | 0.079 | −0.056 | 0.041 |
| *FinCon* | 0.007 | 0.029 | 0.022 | 0.015 | 0.022 | 0.018 | 0.023 | 0.022 | 0.005 | 0.054 | 0.068 | 0.041 |
| *Listed* | 0.102*** | 0.033 | 0.044** | 0.018 | 0.044*** | 0.015 | 0.054** | 0.022 | 0.141** | 0.070 | 0.074 | 0.051 |
| *Reins* | 0.171 | 0.190 | 0.015 | 0.076 | 0.015 | 0.074 | 0.047 | 0.088 | 0.168 | 0.151 | 0.185 | 0.115 |
| *GinGDP* | 3.537*** | 1.116 | −11.120 | 1.978 | −11.120*** | 3.402 | −11.300*** | 3.831 | 3.752** | 1.817 | 2.519 | 1.634 |
| *Inf* | −7.981*** | 1.519 | −22.370*** | 2.701 | −22.370*** | 5.355 | −22.320*** | 5.517 | −7.922** | 3.221 | −5.667 | 2.978 |
| *GinIR* | −0.309** | 0.118 | −0.105 | 0.091 | −0.105 | 0.166 | −0.140 | 0.164 | −0.280 | 0.174 | −0.353 | 0.162 |
| SMRet | −0.491*** | 0.040 | −1.201*** | 0.089 | −1.201*** | 0.172 | −1.189*** | 0.187 | −0.497*** | 0.096 | −0.507 | 0.094 |
| *Year dummies* | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| Adjusted $R^2$ | 0.53884 | | | | | | | | | | | |
| F-value (p-value) | 3367.560***(0.000) | | 167.020***(0.000) | | | | 186.658***(0.000) | | | | | |
| $\lambda^2$ (p-value) | | | | | 242.620***(0.000) | | | | 285.240***(0.000) | | 335.5***(0.000) | |
| No. of Obs. | 276 | | 276 | | 276 | | 276 | | 258 | | 276 | |
| # of instruments | | | | | | | | | 199 | | 218 | |

Table 6 Quantile regression estimation of the RBC regime adoption effects on loss ratio

Note: ***, **, and * indicates statistical significance at the 1%, 5%, and 10% level, respectively.

| | Loss ratio quantiles | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Variables | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
| *ImpRBC* | 0.605*** | 0.642*** | 0.236*** | 0.236*** | 0.021*** | −0.247*** | −0.365*** | −0.950*** | −1.541*** |
| *PDereg* | −0.669*** | −0.796*** | −0.313*** | −0.118*** | −0.049*** | 0.265*** | 0.082*** | 0.977*** | 1.718*** |
| *LR*-1 | 0.176*** | 0.412*** | 0.364*** | 0.290*** | 0.368*** | 0.302*** | 0.373*** | 0.489*** | 0.420*** |
| *LR*-2 | 0.079*** | −0.069*** | 0.076*** | 0.026*** | 0.051*** | 0.053*** | −0.124*** | −0.033*** | −0.161* |
| *Size* | −0.051*** | 0.045*** | 0.019*** | −0.011*** | −0.038*** | −0.049*** | −0.150*** | −0.108*** | −0.303*** |
| *InsLev* | 0.043*** | 0.080*** | −0.000 | 0.055*** | −0.001*** | 0.007*** | −0.006 | 0.014*** | −0.003 |
| *LoBCon* | 0.395*** | 0.567*** | 0.268*** | 0.226*** | 0.122*** | 0.084*** | −0.037*** | −0.144*** | −0.237*** |
| *InvY* | 0.042*** | 0.264*** | 0.063*** | 0.151*** | −0.366*** | 0.220*** | 0.056*** | −0.026** | −0.191 |
| *Age* | 0.014*** | −0.140*** | 0.022*** | 0.006 | 0.032*** | 0.002* | 0.079*** | −0.005 | 0.016 |
| *FinCon* | 0.022*** | 0.086*** | 0.012 | 0.045*** | 0.033*** | −0.001** | 0.152*** | 0.017*** | −0.101* |
| *Listed* | 0.080*** | −0.226*** | 0.069*** | 0.139*** | 0.031*** | 0.011*** | 0.019*** | 0.021** | 0.123** |
| *Reins* | −0.018*** | −0.139*** | −0.018** | 0.172*** | −0.101*** | 0.027*** | 0.135*** | −0.039*** | 0.133 |
| *GinGDP* | 2.669*** | 3.052*** | 3.817*** | 3.371*** | 4.420*** | 3.719*** | 3.330*** | 3.782*** | 6.522*** |
| *Inf* | 14.400*** | 12.740*** | 10.720*** | 8.496*** | 7.139*** | 5.400*** | 4.127*** | −5.371*** | −9.380*** |
| *GinIR* | −0.158*** | −0.192*** | −0.040*** | −0.182*** | −0.137*** | −0.139*** | 0.107*** | −0.167*** | −0.071 |
| *SMRet* | −1.068*** | −0.924*** | −1.106*** | −0.919*** | −0.905*** | −0.857*** | −0.849*** | −0.735*** | −0.800*** |
| *Year dummies* | | | | | Yes | | | | |
| *N* | | | | | 276 | | | | |

Figure 2 illustrates the RBC regime adoption effects on loss ratio under various loss ratio quantile conditions. The results show that the RBC regime adoption increases and decreases the loss ratio for insurers with low and high loss ratios, respectively, thus supporting hypothesis 2.[16] These results further suggest that the RBC regime adoption has achieved its intended purpose. Insurers with low loss ratio Insurers take aggressive underwriting strategies to increase underwriting risk to compensate for the high cost of holding excess capital. In contrast, insurers with a high loss ratio put great effort into loss prevention and mitigation activities to decrease underwriting risk.

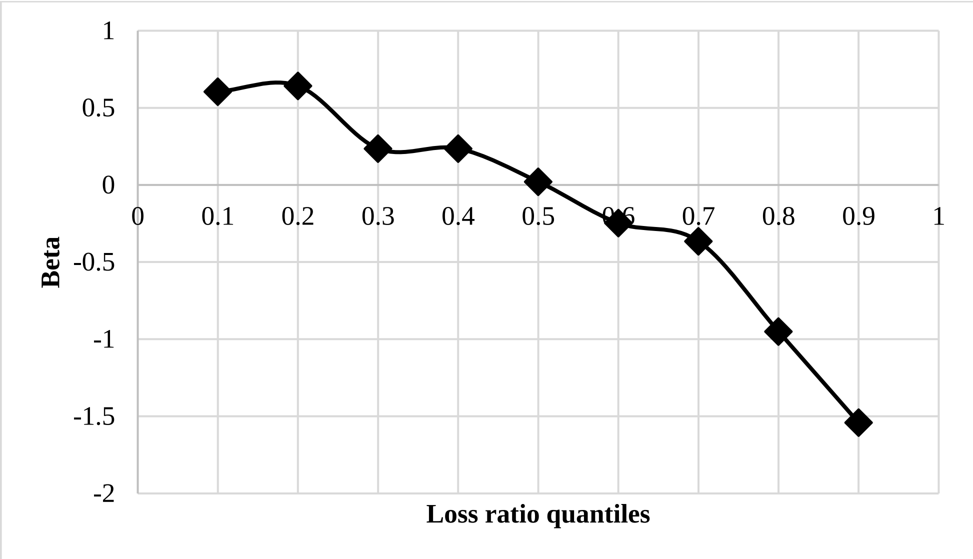


Figure 2 Estimated beta values of the RBC regime adoption effects for different loss ratio quantiles

## 5.3 Testing for Endogeneity

Based on extant literature, endogeneity may exist between reinsurance and loss ratio because loss ratio is a reinsurance usage determinant (Shiu and Hsiao, 2014).

16 In this study, we regard insurers as those with high and low loss ratio when the loss ratio percentiles range from 0.6 to 0.9 and from 0.1 to 0.4, respectively.

However, Powell and Sommer (2007) and Adams, Hardwick, and Zou (2008) note that insurance leverage also determines reinsurance usage. Furthermore, leverage and reinsurance can be simultaneously determined (Shiu, 2011). Thus, we expect that reinsurance and insurance leverage may be potentially endogenous variables introducing bias into the main effects.

The main structural equation in our study is expressed as follows:

$$LR_{i,t} = f\left(Reins_{i,t}, InsLev_{i,t}, ImpRBC_t, CV_{i,t}\right) + \varepsilon_{4,i,t} \tag{4}$$

where $Reins_{i,t}$ and $InsLev_{i,t}$ are reinsurance and insurance leverage, respectively, at time *t*, with both of these variables being potentially endogenous; $ImpRBC_t$ is an exogenous variable that indicates whether the RBC regime is adopted or not; the control variables $CV_{i,t}$ include a combination of variables that are exogenous at time *t*; and $\varepsilon_{4,i,t}$ is the residual term of Equation (4).

We refer to Ho, Lai, and Lee (2013) and adopt the Durbin–Wu–Hausman test to examine whether reinsurance and insurance leverage variables are endogenous. The Durbin–Wu–Hausman test is a widely used method for testing endogeneity using two-stage least squares models. In the first stage, we regress potentially endogenous variables on all of the exogenous and instrumental variables. In the second stage, we introduce the residuals obtained from the first stage into the main structural equation, Equation (4). If the coefficient on the residual of the potentially endogenous variable significantly differs from zero, then the variable is endogenous. Then, we can use the fitted value of the endogenous variable to replace the original value and introduce it into the main structural equation.

All appropriate instrumental variables must be selected before employing the Durbin–Wu–Hausman test. Wooldridge (2016) reveals that instrumental variables must correlate with endogenous variables but not with errors. We select reinsurance, insurance leverage, and line-of-business concentration, all of which are lagged by 1 year, as our potential instrumental variables. In the next stage, we create reduced form equations, comprising potentially endogenous variables, instrumental variables, and all exogenous variables.

The reduced form equations are expressed as follows:

$$Reins_{i,t} = f\left(Reins_{i,t-1}, InsLev_{i,t-1}, LoBCon_{i,t-1}, ImpRBC_t, CV_{i,t}\right) + v_{5,i,t} \quad (5)$$

$$InsLev_{i,t} = f\left(Reins_{i,t-1}, InsLev_{i,t-1}, LoBCon_{i,t-1}, ImpRBC_t, CV_{i,t}\right) + v_{6,i,t} \quad (6)$$

where the dependent variables in both equations are reinsurance (*Reins*) and insurance leverage (*InsLev*) at time *t*; $Reins_{i,t-1}$, $InsLev_{i,t-1}$, and $LOBCon_{i,t-1}$ denote reinsurance, insurance leverage, and line-of-business concentration, respectively, at time $t - 1$; $ImpRBC_t$ is an exogenous variable that denotes whether the RBC regime is adopted at time *t*; the control variables $CV_{i,t}$ include all exogenous variables at time *t*; $v_{5,i,t}$ and $v_{6,i,t}$ are the residual terms from Equations (5) and (6).

Based on the weak instrument test (Stock and Watson, 2007), we examine whether the three instrumental variables $Reins_{i,t-1}$, $InsLev_{i,t-1}$, and $LoBCon_{i,t-1}$ correlate with *Reins* and *InsLe*v. We begin by constructing the null and alternative hypotheses for Equations (5) and (6). The null hypothesis holds that the coefficients on the instrumental variables are not significantly different from zero, whereas the alternative hypothesis states that one of the coefficients on the instrumental variables significantly differs from zero. Then, we can examine whether the coefficients on the instrumental variables significantly differ from zero.

The untabulated results reject the null hypothesis. The respective F-values of the joint hypothesis test on the instrumental variables for Equations (5) and (6) are 371.22 and 4.96, respectively. These results indicate that at least one of the coefficients differs from zero, thereby indicating that the instrumental variables correlate with *Reins* and *InsLev*.

In the next stage, we follow Wooldridge (2016) and employ the overidentification test to examine whether the 1-year lagged *Reins*, *InsLev*, and *LoBCon* correlate with the error term. The results show that the Hansen J-statistics value is 1.45, which is insignificant at the 10% level. Thus, these instrumental variables are not correlated with the error term. Therefore, 1-year lagged *Reins*, *InsLev*, and *LoBCon* are appropriate instrumental variables.

Then, we apply the Durbin–Wu–Hausman test to examine whether potential endogenous variables exhibit endogeneity. In the first stage, we regress potential endogenous variables (*Reins* and *InsLev*) on all exogenous and instrumental variables to create the residuals $v_{5,i,t}$ and $v_{6,i,t}$. In the second stage, we place the residuals $v_{5,i,t}$ and $v_{6,i,t}$ into Equation (1) to create Equation (7):

$$LR_{i,t} = f\left(Reins_{i,t} + InsLev_{i,t} + ImpRBC_t + CV_{i,t}\right) + \alpha_1 \cdot v_{5,i,t} + \alpha_2 \cdot v_{6,i,t} + v_{7,i,t} \quad (7)$$

Then, we can then develop the null and alternative hypotheses on the coefficients of the residuals; the respective hypotheses are $H_0$: $\alpha_1 = 0$, $H_1$: $\alpha_1 \neq 0$ and $H_0$: $\alpha_2 = 0$, $H_1$: $\alpha_2 \neq 0$. Then, we use t-test statistics to examine whether the coefficients on the residuals significantly differ from zero. If the coefficient shows a significant (insignificant) result, then the null hypothesis is rejected (not rejected). Therefore, whether endogeneity exists or not in the potential endogenous variables is determined. The results show that neither of the residuals is significantly correlated, thereby indicating that reinsurance and insurance leverage are not endogenous variables in our analysis.

# 6. Additional Analysis

We provide further analysis of whether the RBC regime adoption has had consistent effects on loss ratio for different direct businesses.[17] Based on the business mix classification in the data, business lines are classified into fire,

17 We investigate the effect of *ImpRBC* on various direct businesses, excluding the reinsurance assumed business, to investigate the direct effect of policy change on Taiwan's property–casualty insurance market. The loss ratio of a direct business is the ratio of direct written loss divided by direct written premium.

automobile, marine aviation and transport, engineering, liability, bonding, and other lines. We exclude observations where the values of *Reins* and *LR* are less than 0 because these observations indicate abnormal operating conditions (Shiu, 2011). Table 7 reports the empirical results of the above business mix using Arellano and Bond's (1991) GMM model.

Although all the coefficients, except the bonding line, reveal negative correlations, they have no consistent significance level. The results reveal significant effects for fire and automobile lines but insignificant effects for marine aviation and transport, engineering, liability, bonding, and other lines. Among these lines, the market shares of automobile and fire line are ranked first and second, respectively, in Taiwan's property–casualty insurance market in terms of direct written premium. In sum, these findings suggest that the RBC regime adoption induces insurers to put great effort into loss prevention and mitigating activities on the business lines they often underwrite.

Table 7 RBC regime adoption effects on the loss ratio of various direct businesses

Note: ***, **, and * indicates statistical significance at the 1%, 5%, and 10% level, respectively.

| Models | Difference GMM | | | | | |
|---|---|---|---|---|---|---|
| Variable | *ImpRBC* | | | | | |
| Lines of business | Coeff. | S.E. | C.V. | Year dummies | N | $\lambda^2$ (p-value) |
| Fire | −2.936** | 1.152 | Yes | Yes | 239 | 226.82*** (0.000) |
| Auto | −0.630*** | 0.225 | Yes | Yes | 258 | 78.180***(0.000) |
| MAT | −0.175 | 0.957 | Yes | Yes | 264 | 81.76***(0.000) |
| Engineering | −1.571 | 1.623 | Yes | Yes | 197 | 108.810***(0.000) |
| Liability | −0.262 | 0.801 | Yes | Yes | 202 | 73.490***(0.000) |
| Bonding | 1.177 | 3.184 | Yes | Yes | 142 | 48.430***(0.000) |
| Others | −2.391 | 1.521 | Yes | Yes | 204 | 46.400** (0.037) |

# 7. Conclusions

This study aims to investigate the RBC regime adoption effects on the underwriting performance of non-life insurers. We find that the RBC regime adoption (1) has improved the underwriting performance of non-life insurers, (2) induces insurers with better and poorer underwriting performance to take aggressive underwriting strategies and put great effort into loss prevention and loss mitigation activities, respectively, and (3) improves the underwriting performance of fire and automobile direct businesses.

In sum, our findings support the importance of the RBC solvency system adoption that has been proven to significantly highlight the need for better underwriting results and has encouraged non-life insurers to go back to basics, focusing on underwriting and claim handling activities, particularly in times of poor underwriting performance. Our findings have important implications. The RBC regime adoption results in different behaviors of insurers with various underwriting performances. Insurers with poor underwriting performance gain awareness of the underwriting risk they take and are encouraged to take measures to reduce the loss ratio for meeting the regulatory standard, thus preventing regulatory action. In contrast, insurers with better underwriting performance tend to take risky underwriting strategies to compensate for the high opportunity cost of holding extra capital because they have sufficient underwriting capacity and hold a high level of capital buffer.

One limitation of our research is that data on actual RBC ratio are not available until 2015. Thus, we only have access to the interval RBC ratio data for the years between 2003 and 2015. However, we have not used these interval data to estimate the correlation between the RBC ratio and loss ratio from 2003 to 2015. The reason is that all the RBC ratio observations in our data have been above 300%

since 2011.

Property–casualty insurers may tend to adjust their investment strategies to control asset-side risk because asset risk is also a major source of risk capital. Thus, future research should extend the scope of our study to examine the RBC regime adoption effects on the asset side of property–casualty insurers. In addition, future research should determine whether the substitution effects or complementary effects are discernible between underwriting risk and asset risk in periods before and after the RBC regime adoption. By doing this, they can evaluate the effects of policy change from the minimum capital requirement regime to the RBC regime.

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Risk-based Capital Regime Adoption and Underwriting Performance: Evidence from the Property–Casualty Insurance Industry in Taiwan

# 採行風險基礎資本制與核保績效：台灣財產保險業的實證結果

陳瑞祥* 張士傑** 許永明***

我們研究採行風險基礎資本制度，會如何影響財產保險的保險人之以損失率為代理變數的核保績效指標。我們的結果顯示：在採行風險基礎資本制度以後，整體損失率已經有顯著下降。然而，對於原本低損失率的保險人而言，損失率會提高，雖然原本高損失率之保險人的損失率會降低。我們進一步發現：實施風險基礎資本制度，降低火災保險與汽車保險直接業務的損失率。我們的發現對於「與最低資本額要求相比，採行風險基礎資本制度讓財產保險業者變得更注意核保風險」之觀念，提供實證上的支持。

**關鍵詞：**風險基礎資本制度之實施，損失率，財產保險的保險人。

JEL: G22, G28.

* 國立政治大學風險管理與保險學系博士候選人，116 台北市文山區指南路二段 64 號；電子郵件：102358501@nccu.edu.tw

** 國立政治大學風險管理與保險學系教授，116 台北市文山區指南路二段 64 號；電子郵件：bchang@nccu.edu.tw

*** 通訊作者。國立政治大學風險管理與保險學系特聘教授，116 台北市文山區指南路二段 64 號；電子郵件：yungming@nccu.edu.tw