國立政治大學風險管理與保險學系

博士論文

三篇保險公司和再保險公司長期關係的研究
Three Essays on the Insurer-Reinsurer Relationship

指導教授：許永明 博士

研究生：陳瑞祥 撰

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中文摘要

在實務與文獻上，概念上皆認為分保公司與再保險人維持愈久的交易關係，有助於提升再保險契約或市場交易的效率。然而，關於再保險交易關係如何影響分保公司的實證研究，非常地稀少。至今僅有幾篇學術研究以理論方式推論或者利用實際資料檢定當再保險交易關係期間愈長時，是否對於分保公司的財務績效、再保險使用程度與破產風險造成影響。因此，當再保險交易關係期間愈長，是否會對分保公司的其他面向營運績效造成影響，是目前學術上尚未探討並且是值得探討的重要問題。

不對稱學習(Asymmetric learning)是再保險交易關係對分保公司造成影響的主要機制，即再保險契約訂立之初，再保險契約交易雙方存在資訊不對稱，此時再保險公司並未清楚分保業務真實的風險程度，因此無法訂立公允的再保險價格。隨著再保險交易關係期間愈來愈久，再保險公司持續地獲得與累積其承保業務的理賠資訊，愈來愈清楚業務的風險性質，並將其資訊用於風險分類與再保險定價。因此，當再保險交易關係期間短時，再保險資訊不對稱程度愈高；然而，當交易關係期間長時，資訊不對稱程度愈低。換句話說，在不同再保險交易關係期間下，分保公司與再保險公司同時面臨不同程度的資訊不對稱現象，因此分保公司面臨不同的誘因並進一步做出對本身有利的決策，進而造成不同面向的影響效果。

除此之外，文獻上捕捉再保險交易關係的指標也稀少，目前文獻發展的指標僅捕捉時間面向的關係，然而，在衡量再保險交易關係時，也必須將再保險交易的金額多寡納入考量，以避免在計算關係指標時納入太多交易金額太少的再保險交易，進而無法捕捉重要的再保險交易關係。因此，本文藉由考量過去五年累積分保保費金額的方式進一步捕捉各種重要性程度的再保險交易關係，即創造同時捕捉時間與交易金額面向的衡量再保險交易關係的指標。

本博士論文由三篇探討再保險交易關係如何影響美國產險業分保公司不同面向的績效所組成，概念上，本論文想要回答以下三個問題，即分保公司的核保利潤、業務多角化與市佔率是否會隨著再保險交易關係期間的增長而隨之變動。換句話說，探討承保活動、風險管理策略與策略績效是否與再保險交易關係有相關。

第一篇文章探討當再保險交易關係期間愈長時，分保公司的損失率、綜合率

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與核保利潤如何受到影響。藉由非線性變數的配置，一階段系統和差分動差法的迴歸模型估計，實證結果顯示，再保險交易關係和損失率與綜合率皆呈現倒 U 型關係，再保險交易關係和核保利潤呈現 U 型的關係。再保險交易關係短的時候，損失率和綜合率會隨著再保險交易關係的延長而增加，核保利潤則會隨之降低。當再保險交易關係久時，損失率和綜合率皆會隨著再保險交易關係的延長而降低，核保利潤則會隨之增加。因此，本文提出實證證據支持不對稱學習假說。

第二篇文章檢視再保險交易關係如何影響分保公司的業務多角化程度，並且探討何種因素調節再保險交易關係與多角化程度的相關性。利用一般最小平方法與隨機效果 Tobit 模型估計，實證結果顯示，當再保險交易的關係持續時，分保公司的商品多角化程度會愈高，也發現公司規模將減緩上述再保險交易關係與多角化程度相關性。因此，本文提出實證證據支持不對稱學習假說與真實服務假說。

第三篇文章則額外考量到市場上同時競爭的保險公司，探討再保險交易關係如何影響分保公司的市占率。藉由非線性變數的配置，一階段系統和差分動差法模型的估計，實證結果顯示，再保險交易關係與市占率呈現倒 U 型關係。因此，本文提供支持不對稱學習假說的證據。

因此，本博士論文提供較完整的證據，回答文獻和實務上尚未回答的問題，即維持愈長期的再保險交易關係，會影響到分保公司哪些面向？再保險交易關係造成的影響效果，是否會隨著累積的交易關係年數而改變？本論文的實證結果可呼應再保險市場依賴長期交易關係的觀點，並且可進一步給實務人士、學術研究者、監理官和要保人等相關的利害關係人提供參考，以供進一步的決策依據。

關鍵詞：再保險交易關係、核保利潤、業務多角化、市佔率、不對稱學習假說

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Abstract

It is well known in practice and in academic research that the efficiency of reinsurance transaction is on the long-term transaction relationship basis. However, how reinsurance relationship has an influence on cedants is an underexplored issue in academic research. Specifically, only few studies derive, theoretically, and examine, empirically, the effects of the tenure of insurer-reinsurer relationship on financial performance, reinsurance usage, and bankruptcy costs of cedants. The questions left to be answered in current reinsurance relationship literature are what other dimensions of cedants could be influenced by the reinsurance relation's duration.

The underlying mechanism of reinsurance relationship is learning over time, called asymmetric learning phenomenon. Specifically, reinsurers could gradually learn the risk of ceded business over time. In addition, the measure of capturing the reinsurance relationship is scarce in recent reinsurance relationship studies. Thus, we also improve such measures by taking the amount of reinsurance premium ceded in the past 5 years into account to capture various level of importance of reinsurance relationship. That is, we construct the reinsurance relationship measure simultaneously considering time and transaction amount dimensions.

Therefore, in this thesis, we present three essays on the effects of the tenure of insurer-reinsure relationship in US property-casualty insurance industry. Conceptually, this thesis intends to answer the questions of how underwriting profitability (underwriting activities), product diversification (risk management strategies), and market share (strategic performance) are affected with the increase of the tenure of insurer-reinsurer relationship.

The first essay investigates how the tenure of insurer-reinsurer relationship affects underwriting profitability, including loss ratio and combined ratio, of cedants. The results document that the tenure of insurer-reinsurer relationship is inverted U-shaped related with loss ratio and combined ratio, respectively. In addition, a U-shaped relationship between the tenure of insurer-reinsurer relationship and underwriting profitability is found. The results are consistent with asymmetric learning hypothesis.

The second essay empirically scrutinizes the effect of reinsurance relationship's tenure on product diversification. The results show that cedants tend to diversify more with the increase of the relation's duration. In addition, we also find that such effect is

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mitigated as the firm size increases. The results are consistent with asymmetric learning hypothesis and real service hypothesis.

The third essay, considering other rivals in insurance markets, empirically investigates the effect of the tenure of insurer-reinsurer relationship on market share. The result documents that such tenure is inverted U-shaped related with market share. The results are also consistent with asymmetric learning hypothesis.

Overall, the implication of this PhD dissertation is that maintaining longer relationship with incumbent reinsurers is beneficial for cedants and various stakeholders, especially for those with long reinsurance relationship.

Keywords：the tenure of insurer-reinsurer relationship、underwriting profitability、product diversification、market share

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Essay 1

The Effect of the Tenure of Insurer-reinsurer Relationship on Insurer's Underwriting Profitability: Evidence from the US Property-casualty Insurance Industry

Abstract

In response to information asymmetry concerns, it is known, in practice and in academic research, that reinsurers rely on building long-term relationship with cedants to mitigate adverse selection and such phenomenon is supported by a prior empirical study suggesting that asymmetric learning exists in U.S. property-casualty reinsurance market. We examine the link between the tenure of insurer-reinsurer relationship and insurers' underwriting profitability by using data of US property-casualty insurers over the period 2013–2020 to fill the gap in the literature. In addition, we improve the reinsurance sustainability measures by considering the amount of reinsurance premium ceded over the past 5 years to capture important reinsurance relationship. The empirical results document inverted U-shaped relationships between the tenure of insurer-reinsurer relationship and loss ratio and between the tenure of insurer-reinsurer relationship and combined ratio. In addition, the results also show that a U-shaped relationship exists between the tenure of insurer-reinsurer relationship and underwriting profitability. These results are consistent with asymmetric learning hypothesis. This study sheds some lights on how long-term relationship in reinsurance market is related to underwriting profitability and may provide implications for practitioners, academics, regulators, policyholder, and other stakeholders.

Keywords: The tenure of insurer-reinsurer relationship, Loss ratio, Combined ratio, Underwriting profitability, (inverted) U-shaped relationship

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1. Introduction

Repeated contracting, which denotes private information develops through time (Shi and Zhang, 2016), have received voluminous attention both among practitioners and academic scholars recently, with many studies devoted to discuss and examine whether information asymmetry or asymmetric learning exists in certain (re)insurance market from Rothschild and Stiglitz (1976). Specifically, it belongs to another form of information asymmetry, suggesting that information asymmetry could be mitigated through long-term relationship since a (re)insurance contract seller (underwriter) could possess private underwriting information on its repeated policyholders/insurers over its rivals through repeated (re)insurance contracting.[1] Thus, insurers retaining with the current reinsurer tend to be low-risk and they could purchase reinsurance at a lower cost due to the mitigation of adverse selection. Furthermore, the level of monitoring by reinsurers increases as the tenure of reinsurance relationship increases. In sum, thus, how the increase of the tenure of reinsurance relationship, through the asymmetry learning mechanism, affects insurer managers' underwriting results in terms of underwriting profit is an interesting issue.

Reinsurance purchased by a cedant is a contract assumed by a reinsurer that make indemnifications for random loss events (Doherty and Tinic, 1981). Moreover, reinsurance is an important risk management tool for property-casualty insurers (Plantin, 2006). Insurers utilize reinsurance for transferring relatively unpredictable catastrophe risk, which is characterized as low-frequency and high severity (Froot and O'Connell, 2008), to mitigate the policyholder's concerns for insolvency risk, to expand their underwriting capacity (Shiu, 2011), to reduce their expected tax payment (Liu et al., 2016), to satisfy stringent regulatory requirements, and to deal with unexpected regulatory changes (Park et al., 2019). From another dimension, purchasing reinsurance equip insurers for having access to the real services provided by reinsurers (Anand et al., 2020).

Underwriting profitability may be impacted differently with various level of the tenure of insurer-reinsurer relationship. Specifically, the level of information asymmetry within reinsurance transaction is higher for insurers with shorter tenure than those with longer tenure based on asymmetric learning hypothesis. Cedants with short

[1] Information asymmetry in reinsurance transaction denotes that insurers possess underwriting information regarding the ceded business that is not attainable to reinsurers when reinsurance contracting.

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reinsurance relationship tend to be high-risk, switch their business to other reinsurers, and tend to be not being renewed by incumbent reinsurers. Managers tend to put less efforts in underwriting and engage in cash flow underwriting to grow new business to increase premium income. However, incumbent reinsurers tend to renew cedants with better loss experience and cedants tend to choose the renew with the incumbent reinsurers since they are prone to be low-risk and could purchase reinsurance at a lower reinsurance premium. In addition, the level of monitoring by reinsurers increases as the relation's duration increases. Thus, managers tend to become more conservative and put more efforts in underwriting and risk classification. Therefore, insurers with longer tenure tends to have lower loss ratio and combined ratio and thus have higher underwriting profit. Therefore, we expect that loss ratio and combined ratio tend to be higher and underwriting profitability tends to be lower when the tenure of insurer-reinsurer relationship is lower. However, we also expect loss ratio and combined ratio tend to be lower and underwriting profitability tends to be higher when the duration of reinsurance relationship is higher.

The existing literature concerning repeated reinsurance contracting, conceptually related to information asymmetry between contracting parties, could be divided into two streams of research. The first stream of research begins with theoretically studies, for example, Rothschild and Stiglitz (1976) investigating information asymmetry, and then extends to empirically scrutinize whether information asymmetry exists in certain (re)insurance market. For instance, Dardanoni, Forcina, and Donni (2018) and Chen and Shiu (2020a) find evidences documenting that information asymmetry exists in insurance and reinsurance market, respectively. The second stream of research considers the learning effects from insurance underwriters theoretically (Nilssen, 2000; de Garidel-Thoron, 2005) and empirically (Shi and Zhang, 2016). In addition, Jean-Baptiste and Santomero (2000) and Garven et al. (2014) theoretically and empirically derive and scrutinize whether asymmetric learning exists in reinsurance markets. However, none of the reinsurance studies explore the effects of the tenure of insurer-reinsure relationship on underwriting profitability of insurers.[2]

The motivation of this study is fourfold. First, practically, it is well known that the

[2] Typically, reinsurance contracts are written on a basis of a fixed term or "continuous until cancellation." Therefore, long-term implicit contracts involve repeated reinsurance contracting or non-cancellation continuously contracting. Specifically, repeated contracting denotes that a reinsurance contract that expires is effectively renewed by reinsurers and rolling over into another reinsurance contract (Garven et al., 2014).

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efficiency of reinsurance market relies on long-term relationship between insurers and reinsurers. Specifically, reinsurers gradually obtain and include such revealed private information into risk classification and reinsurance pricing and then charge the reinsurance premium corresponding to the risk type of the ceded business. In addition, insurers could choose to retain with incumbent reinsurers or switch to other reinsurers to reduce the cost of risk transferring. Moreover, insurers are monitored by reinsurers. Therefore, insurer's underwriting activities may be influenced under various levels of the tenure of insurer-reinsurer relationship. Thus, this study intends to explore whether long-term relationship in reinsurance market influences the underwriting profitability. Second, the current information asymmetry literature chiefly examines whether information asymmetry or asymmetric learning phenomenon exists in various (re)insurance markets (Cohen and Siegelman, 2010). Many studies examining asymmetric learning hypothesis in certain insurance markets focus on how repeated contracting behaviors or other types of behaviors affects loss ratio, underwriting risk, of policyholders at individual level. However, only Garven et al. (2014) empirically investigate the issue related to repeated reinsurance contracting and find evidences supporting that asymmetric learning exists in US property-casualty industry at the company level. Therefore, this study extends Garven et al. (2014), in terms of empirical results and the dimension of investigation, and provides underlying mechanism of how long-term reinsurance relationship affects underwriting profitability of insurers.

Thirdly, current information asymmetry literature examined whether asymmetric learning exists by investigating linear relationship between policy age and risk on insurance market (Cohen, 2012; Shi and Zhang, 2016) and link between the tenure of insurer-reinsurer relationship and return on assets, credit quality, and reinsurance in reinsurance market (Garven et al. 2014). However, unlike individual policyholder, insurers could adjust their underwriting activities to alter their composition of insurance pool and thus their loss ratio, combined ratio, and underwriting profitability may be influenced differently under various levels of relationship's tenure. Therefore, this study examines such effects by specifying non-linear specification to capture the complete effects of all levels of the reinsurance relationship's tenure. Fourthly, we improve reinsurance sustainability measure by following the prior relationship literature and considering the amount of reinsurance premium ceded in the past 5 years. Specifically, it is expected that a reinsurance relationship is considered as an important

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relationship when the amount of reinsurance premium ceded in the past 5 years is significant. Therefore, we additionally consider various important reinsurance relationship in estimating such effects to scrutinize whether such effects differ across various reinsurance sustainability measures.

This study is close to Garven et al. (2014). Both of this study and Garven et al. (2014) investigate the effects caused by a rise in tenure of insurer-reinsurer relationship in US property–casualty insurance industry. However, this study and Garven et al. (2014) are different in terms of several dimensions. Garven et al. (2014) examine the existence of asymmetric learning phenomenon in US property-casualty insurance industry. Specifically, they investigate the relationship between the tenure of insurer-reinsurer relationship and return on asset, reinsurance, and credit quality and provide evidences supporting the three hypotheses derived theoretically by Jean-Baptise and Santemero (2000). However, this study investigates how underwriting profitability is affected as the duration of reinsurance relationship increases. Specifically, we focus on operating results of underwriting activities, excluding investment activities. Another difference is that we improve the measure of reinsurance sustainability by considering the amount of reinsurance premium ceded of past 5 years to capture important reinsurance relationship. The other difference is that this study finds that (inverted) U-shaped relationship exists but Garven et al. (2014) find that the relationship is linear. Thus, this study extends Garven et al. (2014) by providing more detailed description of how reinsurance relation's duration affects underwriting profitability under various levels of reinsurance relationship.

This study uses NAIC (National Association Insurance Commissioner) data to examine how insurers' loss ratio, combined ratio and underwriting profitability are impacted with the increase of the tenure of insurer-reinsure relationship in US property-casualty industry covering the year from 2013 to 2020 by using one-step GMM-difference and one-step GMM-system models to mitigate the dynamic panel data bias. First, we provide primary evidences supporting that information asymmetry exists when the level of relation's duration is low and is mitigated when the duration of reinsurance relationship is long, consistent with asymmetric learning hypothesis. Then, the empirical results show that the tenure of insurer-reinsurer relationship is complex inverted U-shaped related to loss ratio and combined ratio. In addition, the result also documents that a complex U-shaped relationship exists between the tenure of insurer-

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reinsurer relationship and underwriting profitability. Specifically, the tenure of insurer-reinsurer relationship increases loss ratio and combined ratio but decreases underwriting profitability when the reinsurance relationship is short. However, the tenure of insurer-reinsurer relationship decreases loss ratio and combined ratio but increases underwriting profitability when the level of reinsurance relationship is long. Finally, we perform reverse causality test to ensure that these effects mentioned above are not affected by dynamic reverse causality.

We provide several contributions as follows. First, the study bridges the research gap in information asymmetry literature and is the first study investigating how repeated reinsurance contracting behaviors affect insurers' underwriting profitability. Specifically, this study provides empirical evidences to answer the questions of how long-term relationship in reinsurance market affects insurers' underwriting activities. Second, different from the traditional predictions of asymmetric learning literature, this study finds that loss ratio and combined ratio decreases with the increase of the reinsurance relation's duration when such level is short but increases as such duration increases when such duration is long. The reasons behind the results denote that insurers are not the same as policyholders. Specifically, they could purchase reinsurance (risk management) at various reinsurance prices and further adjust their underwriting strategies. Otherwise, this study may provide another direction for the development of relationship literature on banking or insurance industry in the future. Specifically, non-linear specification may provide a more detailed analysis to capture the effects of relationship under various levels of relationship. Thirdly, this study contributes reinsurance relationship literature by taking amount of reinsurance premium ceded in past 5 years into account to capture various reinsurance relationship. Specifically, this study construct reinsurance sustainability measures by containing time and amount dimensions. Fourthly, this study could assist regulators, reinsurer and insurer managers, policyholders, investors, and other stakeholders to realize why keeping longer-term relationship with reinsurers alter the underwriting profitability under various levels of the tenure of insurer-reinsurer relationship. Thus, this study should provide practical implications.

The organized structure of this essay presents as follows. This study reexamines information asymmetry literature and develops hypotheses regarding how loss ratio, combined ratio, and underwriting profitability are affected by a rise in the tenure of

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insurer-reinsurer relationship in the next section. The third section presents the data source, the descriptions of sample, variable specifications, and regression models to lead readers to realize the research methodology. The fourth section presents and explains whether empirical results are shown as expected and consistent with our hypotheses derived in the previous section. Specifically, we additionally perform information asymmetry testing and reverse causality testing in this section. Final section concludes and discuss the limitation of our research and future research.

2. Literature Review and Hypothesis Testing

We first review information asymmetry literature and further introduce the recent research boundary and research gap. Next, we derive three testable hypotheses regarding how the tenure of insurer-reinsurer relationship influences insurer's loss ratio, combined ratio, and underwriting profitability.

2.1 Literature review

Modigliani–Miller irrelevant theorem denotes that the insurers could not obtain advantage from purchasing reinsurance (Modigliani and Miller, 1958). However, frictions exist in real world and thus purchasing reinsurance could provide benefits to insurers since reinsurance (risk management tool) mitigates agency problem, for example, underinvestment problem and asset substitution (Shiu, 2011). Afterwards, many academic studies begin to investigate the determinants of reinsurance usage and how reinsurance impacts the performance of insurers.[3]

In addition, another stream of research investigates whether information asymmetry exists in insurance and reinsurance markets (Cohen and Siegelman, 2010; Yan and Hong, 2015). The concepts regarding information asymmetry in reinsurance contracts denote that reinsurance buyers, cedants, have information advantages about their underlying risk and the underwriters, reinsurers, are short of such underwriting information and put them into (re)insurance pricing, causing the reinsurance price deviate the fair price. Many insurance studies examine whether information asymmetry

[3] Concerning the determinants of reinsurance usage, Altuntas, Garven, and Rauch (2018), Park et al. (2019), Yanase and Limpaphayom (2017) and Ho (2017) investigate the determinants of reinsurance usage. Concerning the effects caused by reinsurance, for example, several reinsurance studies investigate the effects of reinsurance on leverage (Sheikh et al., 2018; Shiu 2011), market share (Upreti and Adams, 2015; Chang, 2019) and loss reserves (Veprauskaite and Adams, 2018).

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exists in certain insurance markets.[4] However, prior studies do not have consistent results and thus it is an empirical question (Cohen and Siegelman, 2010).

However, few studies focus the information asymmetry issues in reinsurance market. This first stream of research concentrates on US property-casualty or Taiwan non-life reinsurance industry. Yan (2013) explored the residual moral hazard phenomena in US property-casualty industry by performing quasi-natural experiment. Specifically, Yan examined, by using fixed effects regression model, the linkage between loss ratio ceded and external reinsurance ratio to capture different extents of moral hazard between external and internal reinsurance transaction. Results show that residual moral hazard phenomena exist in the business line of homeowners reinsurance but does not exist in other two business lines. Yan and Hong (2015) explore whether information asymmetry exists in US property-casualty reinsurance industry by using the NAIC data, covering the year from 1995 to 2000, by examining the linkage between reinsurance and loss ratio and by using fixed effects regression model. Their results document that information asymmetry exists in private passenger auto liability and homeowners business lines but does not exist in product liability business line.

Some studies concentrate on the non-life reinsurance industry in Taiwan. Chen and Shiu (2020a) explored the information asymmetry phenomena in Taiwan non-life reinsurance market. Specifically, information asymmetry phenomena are found and the level of information asymmetry rises with the worsening of loss ratio. Moreover, they perform quasi natural experiment, by using the adoption of risk-based capital regime as an exogenous event, to further find that moral hazard phenomena are the main consequence of information asymmetry in Taiwan non-life reinsurance market. Chen and Shiu (2020b) is another study concentrating on Taiwanese non-life fire reinsurance market. However, their evidences support that information asymmetry does not exists in Taiwanese non-life fire reinsurance market.

Asymmetric learning is another stream of research that is well developed theoretically and empirically on insurance market but not on reinsurance market.[5] In

[4] Prior studies on information asymmetry focus on crop insurance (He et al., 2018), private accident insurance market (Spindler, 2015), automobile insurance market (Gao, Powers and Wang, 2017), private health insurance (Olivella and Vera-Hernández, 2013), cancer insurance market (Wang et al., 2011), and private long-term care insurance market (Browne and Zhou-Richter, 2014).

[5] In labor economics literature, some scholars developed models and argued that incumbent employers have more superior information concerning the ability of their future employee’s working ability than do future employers (Laing, 1994). In credit market literature, banks gradually obtain and accumulate past lending business information of borrowers and they further reject loans to riskier borrowers (Dell'Ariccia,

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other words, asymmetric learning on various insurance market has been attracted considerable attention (Cohen, 2012).[6] On one hand, theoretically, both Kunreuther and Pauly (1985) and de Garidel-Thoron (2005) developed models and argued that insurers pile up more information regarding the quality of repeat policyholders or customers than do their rival insurers. On the other hand, the insurance underwriters obtain achieve higher profits and market power from repeated customers (Cohen, 2012) since the extent of the reduction in insurance premium charged by incumbent insurers is lower than the reduction in insurance payouts related to these incumbent policyholders (Kofman and Nini, 2013).

However, there is no consensus on whether asymmetric learning phenomena exist in insurance market or not, suggesting that it is also an empirical question. For instance, Cohen (2012) find that learning over time phenomenon by insurers exist in an Israeli automobile insurance portfolio. Wu and Lin (2009) discover that policyholders renewing their policies with incumbent insurers are more profitable to insurers than those switching frequently between other insurers. They assert that the latter tend to be poor risks. Shi and Zhang (2016) find that the insurers, in insurance market, updates and accumulates more underlying information concerning riskiness of their policyholders' through observing over time and thus profit more with low-risk repeat customers. Their results suggest that low-risk customers tend to contract with the insurer longer, driving higher profits for insurers. It is vital that they are offered a premium corresponding the risk that is higher than that of fair actuarial risk level. Eling et al. (2017) simultaneous explore whether both information asymmetry and asymmetric learning exist in group insurance. First, their results present evidences supporting the notion that adverse selection exists in group insurance. Moreover, they also find that asymmetric learning exists, indicating adverse selection gradually disappears over time when the group continue renewing and staying with the incumbent

Friedman and Marquez, 1999) since a bank acquires more market power through retaining safer borrowers than do other banks. Petersen and Rajan (1994) found that a borrower having a long-term relationship with a bank could obtain more credit since banks acquire and accumulate borrower's quality information over time, reducing the information asymmetry between borrowers and banks.

[6] The insurer acquires underwriting information associated with the risk type of repeat policyholders and further offers lower premium for low-risk policyholders and higher premium for high-risk policyholders. For policyholders, they tend to purchase insurance with lower price. Hence, policyholders with poor claim records tend to fleet their poor records to leave their current insurers and purchase from other insurers, causing adverse selection, since the other insurers do not have complete information regarding the riskiness of the insurers. Those insurers with better claim records tend to stay for another term of the insurance contract.

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insurer. However, Kofman and Nini (2013) find evidences showing that loss ratio and policyholders' tenure is negatively related, but such effect is completely based on information observable for insurers, suggesting that asymmetric learning does not exist.

Concerning research on reinsurance market, asymmetric learning denotes repeated contracting between reinsurers and insurers. The concept of asymmetric learning in reinsurance market is that a reinsurance seller (reinsurer) learns and accumulates underwriting information of ceded business and has more private information about the ceded business than other potential reinsurance providers have. Compared to studies focusing on insurance market, theoretical and empirical related studies are sparse. Theoretically, only Jean-Baptiste and Santomero (2000) derive how information asymmetry is mitigated by maintaining long-term relationships between reinsurers and insurers. Specifically, they derive three hypotheses representing the existence of asymmetric learning. Afterwards, Garven et al. (2014) empirically explore whether reinsurance, financial performance, and credit quality increase with the increase of the tenure of insurer-reinsurer relationship. They find that all of three variables increases with the increase of reinsurance sustainability, consistent with the three hypotheses proposed by Jean-Baptiste and Santomero (2000). Overall, their results indicate asymmetric learning exists in US property-casualty reinsurance industry.

Based on the previous discussions, we find that prior studies concentrating on the issues of insurer-reinsurer relationship are sparse. To bridge the gap and advance the literature, thus, we explore how underwriting profitability is affected as the tenure of insurer-reinsurer relationship lengthens.

2.2 Hypothesis Development

In this section, we derive three testable hypotheses on how insurers' underwriting profitability was affected as the tenure of insurer-reinsurer relationship lengthens. Besides, loss ratio and combined ratio are also regarded as underwriting profitability of insurers (Pooser and Browne, 2018). To be more specific, this study derives the hypotheses regarding how loss ratio, combined ratio, and underwriting profitability are impacted as the tenure of insurer-reinsurer relationship lengthens, respectively.

The US property-casualty insurance industry is characterized as a completely competitive market in terms of insurance products, services, and the number of insurers

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(Chang, 2019).[7] Specifically, insurers are competing hard, in terms of price and quantity, against each other. For insurers, it is relative difficult to attract new customers. Nevertheless, reinsurance equips insurers have comparative advantage over rivals in insurance market by providing higher underwriting capacity and real service and thus enables insurers to grow their business (Upreti and Adams, 2015; Anand et al., 2020). However, reinsurance costs much (Cummins et al., 2021).

Although reinsurers are professional underwriters, information asymmetry still exists in reinsurance market. Specifically, there are no information sharing systems between reinsurers. In addition, reinsurance brokers may strengthen such phenomenon since their advice quality and price are lower and higher than social optimal (Sonnenholzner, Friese, and Schulenburg, 2009).[8,9] Specifically, poor advice quality may occur within the reinsurance transaction and reinsurance brokers have incentives to pretend high-risk business as low-risk business for better reinsurance terms and price to acquire higher reinsurance commissions from reinsurers.[10] Moreover, cedant managers also have incentives to hide the real riskiness of the ceded business and pretend the high-risk business as low-risk business, generating high level of private information for cedants and using such superior information into reinsurance purchasing decisions. Initially, reinsurers regard new business as average-risk business since they do not possess enough information to distinguish whether such new business is high-risk or low-

[7] Specifically, Shim (2017) indicates that the U.S. property-casualty industry is very competitively and complicated structured from the angle of the number of insurers, the types of insurance products and insurance real services because there are over 2,500 property-casualty primary insurers compete against each other.

[8] In the context of reinsurance broker markets, advice quality is considered as the extent of reinsurance brokers' comprehending mismatches regarding cedants to boost the reinsurance selling probability (Gravelle, 1994). In addition, price solely means the broker's markup instead of the overall reinsurance price regarding a reinsurance policy purchased from a reinsurance broker.

[9] Reinsurance brokers have become more and more important within the distribution of reinsurance. Specifically, reinsurers alleviate the searching costs through the channels of reinsurance brokers but they also must pay reinsurance commissions. Over the decades, the US reinsurance broker market is confronted with a high level of consolidation and thus it is experiencing the detrimental effects from the increasing market power. However, their advice quality is lower than the social optimum and they charge higher price than social optimum for their service provision. Specifically, reinsurance brokers are unwilling to place time and resources into improving their advice quality since the cost structure shows increasing and convex (Sonnenholzner, Friese, and Schulenburg, 2009).

[10] Reinsurance brokers tend to have incentives to be dishonest to enhance their self-interest by maximizing their expected return under the commission system (Gravelle, 1994). Moreover, they tend to sell reinsurance policies sold by other reinsurers paying high reinsurance commissions (Marvel, 1982). Thus, a reinsurance broker may tend to not be truthful and further lure a cedant to purchase the reinsurance policy even though that cedant could be more profitable without reinsurance.

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risk.[11,12] Furthermore, information asymmetry results in adverse selection and moral hazard phenomena (Cohen and Siegelman, 2010). Specifically, adverse selection in reinsurance market indicates that cedants have information regarding their risk type that reinsurers underwriting the ceded business lack. In addition, cedants make use of such information in reinsurance purchasing decisions (Cohen and Siegelman, 2010).[13] Moral hazard denotes that insurers relax their due efforts of loss prevention and mitigation ex post. Both phenomena deteriorate underwriting profitability of reinsurers, and thus reinsurers adopt measures to mitigate adverse selection by learning over time (Garven et al., 2014) and moral hazard by monitoring (Doherty and Smetters, 2005) and by specifying deductibles, coinsurance rate, experience rating and retrospective rating in reinsurance contracts when negotiating reinsurance contracting.

Specifically, the key mechanism, rooted in the central idea related to contract theory, is asymmetric learning hypothesis, which mitigates of adverse selection through the revelation of claims of ceded business over time. In the context of reinsurance market, asymmetric learning exists in US property-casualty reinsurance industry (Gaven et al., 2014). Specifically, incumbent reinsurers acquire observed information in terms of claims incurred into reinsurance pricing (Jean-Baptiste and Santomero, 2000) and monitoring (Doherty and Smetters, 2005). Specifically, private information that cedants used in reinsurance purchasing and reinsurers lack gradually obtained by reinsurers over time, indicating that the information advantage in terms of cedants diminished over time. With more information, on one hand, reinsurers charge high reinsurance premium or stop renewing for high-risk ceded business. On the other hand, they offer lower reinsurance premium for ceded business with better loss experience. For insurers, managers tend to purchase reinsurance with the reinsurer providing a lower reinsurance premium to minimize the cost of reinsurance (risk management). Specifically, insurers

[11] Insurers (cedants) have all reachable information of riskiness concerning the underwriting business. Specifically, insurers underwrite and provide services to policyholders directly in insurance market. However, reinsurers do not underwrite the business directly from policyholders and they could only acquire the related information provided by insurers since reinsurance is the second layer of insurance (Jean-Baptise and Santomero, 2000). Specifically, they have no access to obtain additional information and further include such information into risk classification and reinsurance pricing to make reinsurance premium fair.

[12] Contrary to the traditionally way of discussions on information asymmetry, we do not discuss from the angle of the riskiness of an insurer. Specifically, we discuss from the angle of ceded business and retained business. To be more precisely, a risky insurer may cede low risk ceded business to a reinsurer and retain risky business. However, reinsurers have interests in the ceded business since the underwriting experience of ceded businesses are related to their underwriting profitability.

[13] Specifically, cedants underwrite the business directly but reinsurers only could acquire related information through cedants.

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ceding business with poor loss experience tend to switch to other reinsurers for fleeting their records and purchasing reinsurance at a lower price. However, insurers ceding low-risk business tend to stay with the incumbent reinsurers for another term since the current reinsurers offer reinsurance at a lower reinsurance premium since other reinsurers are uncertain about their quality of ceded business. Thus, insurers with long reinsurance relationship tend to have less private information but those with short relationship also tend to have more private information. Specifically, insurers take different underwriting strategies at different levels of the tenure of insurer-reinsurer relationship due to different levels of private information.

Since we argue that the tenure of insurer-reinsurer relationship-loss ratio and insurer-reinsurer relationship-combined ratio relationships are both complex inverted U-shaped associated and the tenure of insurer-reinsurer relationship-underwriting profitability is U-shaped related, we discuss the tenure of insurer-reinsurer relationship effects under various of its levels to make a detailed and complete derivations and explanations. First, we start from the short reinsurance relationship condition. Second, we further discuss how such effects adjust when the level of relation's duration increases. Finally, we discuss the long tenure condition.

At low level of the tenure of insurer-reinsurer, managers of insurers tend to take advantage of reinsurers and take aggressive underwriting strategies to grow new business by purchasing reinsurance. For reinsurers, although they "experience rate" the previous loss experience of direct business to alleviate information asymmetry phenomena (Yan, 2013), adverse selection is still high since cedant have high level of private information that cannot be accessed by reinsurers. Specifically, at this stage, reinsurers could not distinguish high-risk from low-risk business and tend to underwrite high-risk ceded business. In addition, moral hazard is also severe since the function of monitoring is weak (Doherty and Smetters, 2005). For insurers, they tend to not only put less efforts in risk classification and loss mitigation but also lessen their underwriting standard to attract many new customers to grow premium income but also frequently switch their ceded business to other reinsurers since their loss experience may be poor.[14] Specifically, they tend to maximize their short-term performance

[14] Since the true riskiness of old policyholders would be gradually revealed after the realization of claim records, the insurers would charge the fair insurance premium close to their true riskiness as the tenure of policyholder-insurer relationship increases. Specifically, insurers would charge a lower insurance premium for less risky policyholders and a higher insurance premium for risky policyholders. When current less risky policyholders are charged by a lower insurance premium, they are more willing to

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without considering renewing reinsurance with current reinsurers. For customers, new customers exhibit high level adverse selection (Cohen, 2005). Specifically, managers of insurers could not have a new customer's complete historical claim records and put such information into risk classification and insurance pricing. In addition, self-reporting submitted by a new customer is incomplete, inaccurate, or underreported (Insurance Research Council, 1991; Cohen, 2012). Thus, combined the discussions from various aspects, adverse selection and moral hazard are severe when the level of insurer-reinsurer relationship is short. Therefore, loss ratio increases as the tenure of insurer-reinsurer relationship increases when the tenure is short.

As the level of the relationship's duration increases, insurers become more prudent and conservative in various underwriting dimensions since the current reinsurers gradually acquire such private information through the loss experience and low-risk insurers tend to retain with the current reinsurance relationship. Specifically, insurers with better loss experience tends to retain with the current reinsurers since insurers with poor loss experience tend to leave the relationship based on asymmetric learning hypothesis. For reinsurers, they gradually have amassed longer period historical underwriting information regarding the riskiness of the ceded business. Furthermore, incumbent reinsurers include such information in risk classification, reinsurance pricing and monitoring the underwriting activities of ceding insurers. Specifically, based on asymmetric learning hypothesis, low-risk insurers tend to retain with the current reinsurance relationship and incumbent reinsurers tend to charge those low-risk insurers lower reinsurance price to make profits (Shi and Zhang, 2016).[15] Furthermore, the extent of monitoring by reinsurers increases as the relation's duration increases (Doherty and Smetters, 2005). In addition, the cost of monitoring lowers and reinsurers pass the savings of reduced monitoring cost to cedants in terms of a lower reinsurance

retain with the current insurer. The composition of insurance pool will mainly be composed of old policyholders, resulting in less commission and advertising expense as the level of the tenure of insurer-reinsurer relationship is shorter. In addition, commissions of renewal business are often lower than that of new business, and other search costs (e.g., advertising) decreases when more current policyholders remain with the current insurer (Pooser and Browne, 2018).

[15] Based on asymmetric learning, dynamic pricing pattern of reinsurance is similar to highballing pattern. It is also called commitment model and assumes that reinsurers (implicitly) commit to experience scheme over time. Specifically, it implies that relatively high reinsurance price in the early stage of reinsurance relationship, and relatively low reinsurance price in the later stage (Cooper and Hayes, 1987; Dionne and Doherty, 1994).

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premium as the insurer-reinsurer relationship intensifies.[16,17] From another aspect, reinsurers could precisely provide real services to insurers as the tenure of insurer-reinsurer relationship lengthens since they are more familiar with the cedants. Specifically, they could assist insurers in underwriting and claim handling activities.

For insurers, managers gradually pursuit both long-term goals as well as short-term goals since they could acquire advantage from longer reinsurance relationship. Specifically, insurers benefit from lower reinsurance premium and more favorable reinsurance terms over time. Thus, managers tend to put more efforts in underwriting and loss mitigation activities and enhancing their underwriting standard to improve their loss experience and efficiency for renewing the reinsurance since the benefits of efforts increases with the increase of reinsurance relationship. In addition, risk-aversion insurer managers tend to be renewed by reinsurers since their tend to be low-risk. Importantly, their opportunity cost of not being renewed by reinsurers increases with the increase of the tenure since the reduction of reinsurance premiums become larger. Specifically, their ceded business is regarded as average-risk ceded business if they switch their business to other reinsurers. Moreover, insurers with longer relationship also retain with current insurers to avoid search frictions (Ioannidou and Ongena, 2010). Therefore, based on the discussions, adverse selection and moral hazard lowers as the tenure of insurer-reinsurer relationship increases.

In sum, at high level of the tenure of insurer-reinsurer relationship, the levels of adverse selection and moral hazard are lower. Specifically, reinsurers have amassed more underwriting private information and incorporate such information into risk classification, reinsurance pricing, and monitoring. Additionally, low-risk insurers tend to retain with the incumbent reinsurers and they are managed to improve loss experience by retaining low-risk customers, employing risk classification, putting more efforts in underwriting and claim handling activities, and keeping monitoring.

[16] In relationship banking literature, as the banking relationship enhanced over time, banks pass the cost savings resulting from the reduced cost of monitoring to borrowers in terms of lower borrowing cost (Bharath et al., 2011).

[17] Cummins et al. (2021) denotes that the capacity shortfall, especially after the huge catastrophe losses, drives the reinsurance price up in reinsurance market. Moreover, agency problem, shareholder-manager incentives conflict, and lack of transparency exist in reinsurers and thus increase the cost of reinsurance capital, making reinsurance price expensive. However, we do not have detailed information regarding the reinsurers to engage in further analysis. Thus, these concerns are not within the scope of this study. In this study, we follow the assumption implied by Jean-Baptiste and Santomero (2000) that showing that contingent pricing schemes (deductibles design and loss-sensitive contracts) becomes less important as the length of relation's duration increases.

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Therefore, based on the discussions, we derive that loss ratio reduces as the tenure is longer. We further propose our hypothesis 1:

Hypothesis 1. The linkage between the tenure of insurer-reinsure relationship and loss ratio is nonlinear, with the slope positive at low levels of the tenure of insurer-reinsurer relationship, and negative at high levels of the tenure of insurer-reinsurer relationship.

Since combined ratio is the summation of loss ratio and expense ratio, we further discuss the expense ratio under low and high level of the tenure of insurer-reinsure relationship. As previous discussed, insurers purchase reinsurance to adopt aggressive underwriting strategies to grow their business by underwriting many new policyholders at low level of the reinsurance relationship. On contrary, insurers would underwrite conservatively and adopt measures to retain old policyholders when the duration of reinsurance relationship is low. In addition, the expense incurred for repeat customers is lower than that for new customers (Pooser and Browne, 2018).[18] Thus, the expense ratio for insurers with short reinsurance relationship may be larger than that of insurers with long relationship. Therefore, we could derive that combined ratio increases as the relation's duration lengthens when the length of the tenure of insurer-reinsure relationship is short but reduces as such reinsurance relationship is long. Thus, we propose our second hypothesis as follows:

Hypothesis 2. The linkage between the tenure of insurer-reinsure relationship and combined ratio is nonlinear, with the slope positive at low levels of the tenure of insurer-reinsurer relationship, and negative at high levels of the tenure of insurer-reinsurer relationship.

Based on hypothesis 1 and 2, we conclude that both loss ratio and combined ratio increase or decrease with the increase of the reinsurance relationship when the levels of

[18] Expense ratio denotes how premium written is paid out in acquisition and service expenses (Pooser and Browne, 2018). Specifically, the ratio could be regarded as a measure for measuring an insurer's efficiency (Sheikh et al., 2018) and expenditures of providing services to policyholders (Klein, 2013). However, expense ratio is higher for new customers than for current policyholders since the marketing expense incurred to retain the existing policyholders is lower than the expense to attracting new customers (Pooser and Brown, 2018).

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such tenure are low and high, respectively. In addition, underwriting profitability is defined as calculated as 1 minus combined ratio. Specifically, it is expected that the higher the underwriting profitability, the lower the combined ratio. Thus, we could conclude that underwriting profitability lowers or increases with the rise of the reinsurance relation's duration when such reinsurance relationship are short or long. Therefore, we propose the third hypothesis:

Hypothesis 3. The linkage between the tenure of insurer-reinsurer relationship and underwriting profitability is nonlinear, with the slope negative at low levels of the tenure of insurer-reinsurer relationship, and positive at high levels of the tenure of insurer-reinsurer relationship.

3. Data, Variable development, and Empirical models

3.1 Data

We use the National Association of Insurance Commissioners (NAIC) database covering the years from 2013 through 2020 to examine the effects of the tenure of insurer-reinsurer relationship on insurer's underwriting profitability, including loss ratio, and combined ratio, in US property-casualty insurance industry.[19] Our data consists of unbalanced panel data. The initial number of property-casualty insurers in 2013 and 2020 are 2983 and 2853, respectively.[20] To alleviate the data concerns mentioned in prior studies, we adopt some sample exclusion criteria rules. Firstly, we exclude the firm-year observation of missing values, negative total admitted assets, negative surplus, negative net premium written, unreasonable or illogical values (Chang, 2019).[21] Secondly, we remove those insurers whose organizational structures are not stock or mutual form (Berry-Stözle et al., 2012). Thirdly, we exclude the insurer that is

[19] The time periods of dependent variable ranges from 2013 to 2020. We include 1-year and 2-year lagged loss ratio, combined ratio, and underwriting profit, as independent variables for controlling underwriting cycle and alleviating omitting variable problems. Precisely, the time periods of loss ratio, combined ratio, and underwriting profitability ranges from 2011 to 2020. Regarding the independent variables, except for the reinsurance sustainability variable, the time periods of independent variables ranges from 2012 to 2019 due to the 1-year lagged variable specifications. Moreover, the time periods of reinsurance sustainability ranges from 2008 to 2019.

[20] After excluding observations based on the sample exclusion criteria rules, the insurers included for analysis do not include the insurers with COCODE less than 10,003.

[21] For example, we exclude the sample observations with negative value of financial leverage (Chang, 2019). In addition, we also exclude the sample observations that the value of reinsurance ratio is below 0 or above 1 (Shiu, 2011).

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regarded as a reinsurer since the ratio of the assumed business is more than 75% of gross business (Cole and McCullough, 2006). Fourthly, we exclude insurers that are not domiciled within the United States (Hsu, Huang and Lai, 2015). Fifth, we exclude insurers having less than 5 years data since the reinsurance sustainability variable needs 5-year consecutive data to construct.

After the elimination, the final number of firm-year observations is 8,544. In addition, we follow Lin et al. (2011) and then winsorize all variables, excluding the dummy variables, at the 1^{st} and 99^{th} percentiles. Since we do not have reinsurance contract level data, therefore, in our analysis, we could not analyze these effects on the reinsurance contract level basis (Garven et al., 2014). The information regarding the counterparty reinsurers and reinsurance transaction for each ceding company is organized from the NAIC Schedule F–Part 3. We could further collect reinsurers' names and the amount of reinsurance premium ceded in the past 5 years to construct the reinsurance sustainability variables.

3.2 Variables

In this section, we outline the variables utilized in this study. We mainly refer to Pooser and Brown (2018) and Garven et al. (2014) to choose our dependent variables and independent variables to test the hypothesis predictions derived from the previous section by examining the relationship between reinsurance sustainability and loss ratio, combined ratio, and underwriting profitability, conditional on other observable variables that are likely to be associated with dependent variables. Table 1 documents all variables abbreviations and definitions.

<Table 1 is inserted here>

3.2.1 Dependent variable

We specify three underwriting profitability measures to investigate the effects of the tenure of insurer-reinsurer relationship on loss ratio ($Loss\_ratio$), denoting the *ex post* underwriting risk (Yan and Hong, 2015) or underwriting performance (Adams and Jiang, 2016) and on combined ratio ($Combined\_ratio$), denoting the primary insurer's overall measure of underwriting profitability in a given year (Cheng and Weiss, 2012; Pooser and Brown, 2018). The loss ratio is a ratio variable, which is defined as the sum of incurred losses in year t plus loss adjustment expenses in year t divided by premium earned in year t (Yan and Hong, 2015). The higher the loss ratio, the higher the

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underwriting risk the insurers take. The combined ratio is the sum of the loss ratio and expense ratio (Che and Liebenberg, 2017).[22] The higher the combined ratio, the worse the underwriting profitability of the insurers. Another measure is underwriting profitability (UW_profit), defined as 1 minus combined ratio.

3.2.2 Independent variable

Reinsurance sustainability

Concerning the main independent variables, we follow Garven et al. (2014) and use reinsurance sustainability index, to capture reinsurance relationship, as our measure of the tenure of the insurer-reinsurer relationship. To create this measure, we employ the following multiple steps. First, we create 8 separate 5-year rolling windows. The periods of the rolling windows include 2008-2012, 2009-2013, 2010-2014, 2011-2015, 2012-2016, 2013-2017, 2014-2018, and 2015-2019, respectively. Second, the years within every 5-year rolling window, indicating that a cedant cedes business to each of its reinsurers, are calculated. Specifically, we calculate both the mean and standard deviation by using each cedant's reinsurance relationship count distribution. The reinsurance sustainability ($Reins\_Sus$) is constructed in equation (1).

$$Reins\_Sus = \frac{\text{mean of the reinsurance relationship count distribution}}{(\text{standard deviation of the reinsurance relationship count distribution}+1)} \quad (1)$$

The numerator value ranges from 0 to 5. Within the reasonable value range, the highest value and lowest value for the numerator and denominator are 5 and 1, respectively. The former indicates that a cedant purchases reinsurance from the same group of reinsurers over the specified 5-year rolling window, and the latter suggest that a cedant purchases reinsurance from the same group of reinsurers only for 1 year and possibly switches the ceded business to other group of reinsurers. Conceptually, we regard persistency as the average value of the reinsurer relationship count distribution and consistency as the standard deviation of the reinsurer relationship count distribution. The higher (lower) the average value, the higher (lower) the persistency of the reinsurance relationship with a given reinsurer. Moreover, the higher (lower) the standard deviation, the lower (higher) the consistency of the reinsurance relationship with a given reinsurer. In sum, a cedant receiving high value of reinsurance

[22] Expense ratio denotes how much of premium revenue is paid out in acquisition and servicing expenses (Pooser and Brown, 2018; Ma and Ren, 2021). The expense ratio is calculated as the ratio of underwriting expenses divided by premium written. The higher the expense ratio, the less operational efficiency of insurers (Lai and Limpaphayom, 2003).

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sustainability maintains long-term reinsurance relationship with the same group of reinsurers, indicating that they have not only high persistency but also high consistency. On contrary, a cedants receiving low value of reinsurance sustainability tend to switch their business to other reinsurance counterparties frequently, denoting that they have low value of persistency and consistency. Specifically, reinsurance sustainability represents a proxy for private information about the riskiness of ceded business that reinsurers lack but used by cedants in reinsurance purchasing decisions. Cedants having low (high) value of reinsurance sustainability have superior (less) information advantage over current reinsurers.

However, the above specified reinsurance sustainability measure may be distorted by the reinsurance transactions with low transaction amount since the reinsurance sustainability measure gives all reinsurance relationships equal weighting when calculating the numerator and denominator. Specifically, such measure may fail to capture important reinsurance relationships by including many non-important reinsurance relationships if such cedant purchase a large amount of reinsurance from few reinsurers but purchase a little amount of reinsurance from many reinsurers. Therefore, we follow the concepts mentioned in prior studies and take the amount of reinsurance premium ceded of the past 5 year's reinsurance transactions into account in constructing different reinsurance sustainability measure.[23] Specifically, we create new reinsurance sustainability measures by two steps. First, we calculate the amount of reinsurance premium ceded over the past 5 years to form the basis of each reinsurance relationship. For example, the given reinsurance relationship represents the relationship between a cedant i and a given reinsurer j within the specified 5-year rolling window. Specifically, to capture important reinsurance relationships, we regard reinsurance transactions with large amount of reinsurance premium ceded as important reinsurance relationships. We further design 4 scenarios for choosing the observations based on the amount of reinsurance premium ceded over the past 5 years. In the second stage, we put the observations into equation (1) and then generate four reinsurance sustainability variables to emphasize various levels of important reinsurance relationships. In addition, such specification enables us to investigate whether "too-big-to-fail" effect for moral

[23] Kysucky and Norden (2016) review and summarize that time, distance, exclusivity, and cross-product synergies are the key dimensions of strong relationship. In addition, Donker, Ng, and Shao (2020) use the amount of loans loaned by banks in the past 5 years to construct banking relationship measures.

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hazard exists if the reinsurance relationship becomes strong.[24]

Next, reinsurance sustainability measure is categorized relied on the amount of reinsurance premium ceded over the past 5 years. The first analysis includes all reinsurance transactions as Garven et al. (2014) did. We define the variable name as $Reins\_Sus\_total$. The second analysis excludes the relationship observations whose values are lower than the value of the 25th percentile of all reinsurance relationships and include the other reinsurance relationship observations. Then, we construct the $Reins\_Sus\_p25$ variable. The third analysis excludes the relationship observations whose values are lower than the value of the 50th percentile of all reinsurance relationships and include the other reinsurance relationship observations. Next, we construct the $Reins\_Sus\_p50$ variable. The fourth analysis excludes the observations whose accumulated reinsurance premium are lower than the 75th percentile of the accumulated reinsurance premium of overall reinsurance transactions. We construct the $Reins\_Sus\_p75$ variable. In sum, we construct 4 reinsurance sustainability variables, including $Reins\_Sus\_total$, $Reins\_Sus\_p25$, $Reins\_Sus\_p50$, and $Reins\_Sus\_p75$.

In addition, we also create and include the squared term of reinsurance sustainability, $Reins\_Sus^2$, to capture the non-linear effects of the tenure of insurer-reinsurer relationship on loss ratio, combined ratio and underwriting profitability.[25] The variables included in this analysis are $Reins\_Sus\_total^2$, $Reins\_Sus\_p25^2$, $Reins\_Sus\_p50^2$, and $Reins\_Sus\_p75^2$.

Based on hypothesis 1 and 2, we expect that the associations between reinsurance sustainability and loss ratio and combined ratio are positive but the associations between the squared term of reinsurance sustainability and loss ratio and combined ratio are negative, indicating that both relationships present complex inverted U-shaped relationship. However, based on hypothesis 3, we expect that reinsurance sustainability is negatively related with underwriting profitability but the squared term of reinsurance

[24] Regarding relationship banking literature, Kysucky and Norden (2016) indicate that a borrower with huge amount of borrowing with banks tend to have incentives to engage in activities resulting in moral hazard in various levels of bank relationships. Specifically, instead of improving their financial condition, the borrower tends to make a gamble by getting more funds from banks.

[25] The empirical method of this study is similar to Kofman and Nini (2013). Kofman and Nini (2013) test the prediction by examining the correlation between the age of a policy and both claim frequency and claim severity, conditional on other observable variables likely to be correlated with claim risk. However, we do not acquire reinsurance contractual level data. Therefore, we examine the association between reinsurance sustainability and loss ratio, combined ratio, and underwriting profitability.

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sustainability is positively related with underwriting profitability, presenting complex U-shaped relationship.

2-year lagged loss ratio, combined ratio, and underwriting profitability

Wooldridge (2016) suggests that the omitting variables problem could be alleviated by introducing lagged dependent variables as independent variables. In addition, based on prior literature, it is evidenced that underwriting cycles prevail in U.S. property-casualty industry (Boyer, Jacquier, and van Norden, 2012). Thus, we follow Berry Stölzle and Born (2012) and Adams, Upreti, and Chen (2019) and employ the second order autoregression model, in terms of 1-year and 2-year lagged loss ratio, combined ratio, and underwriting profitability, to control the phenomena of underwriting cycles between hard-type and soft-type markets (Cummins and Outreville, 1992; Harrington and Yu 2003).

Firm size

Size is measured as the natural logarithm of an insurer's total net admitted assets (Che and Liebenberg, 2017).[26] Larger insurers, due to having lower bankruptcy cost (Warner, 1977), achieving economies of scale, resulting in lower cost of risk management, and having the access and the ability to raise necessary capital in the short run or in emergency (Mankay and Belgacem, 2016), have more underwriting capacity and higher risk tolerance (Shiu, 2016). Additionally, they possess more resources to not only retain but also attract many talented managers to write riskier and complicated business and further achieve operational efficiencies (Hardwick et al., 2011). Cummins and Zi (1998) document that large insurers, in U.S. property-casualty insurance industry, exhibit higher operational efficiencies than smaller counterparts. Therefore, we expect firm size is positively correlated with loss ratio, combined ratio, and underwriting profitability, respectively.

Financial Leverage

Financial leverage is measured as the ratio of total liabilities to total admitted assets (Huang et al., 2020). Specifically, insurers having high leverage exhibit higher

[26] Pottier and Sommer (1997) and Adams, Burton, and Hardwick (2003) indicate that the distribution of total assets among insurers in the insurance industry is highly skewed.

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insolvency risk than those with low leverage (Mankai and Belgacem, 2016). The insurers may further underwrite aggressively by reducing the standard of risk assessment and thus insurance price (Adams, Upreti, and Chen, 2019) to retain existing risky policyholders and attract new customers to generate free cash flow to reduce bankruptcy risk (Chang, 2019).[27] However, since insurers are subject to heavily ongoing statutory solvency monitoring (Serafeim, 2011), the insurer managers underwrite more cautiously to mitigate bankruptcy risk (Chang, 2019). In addition, policyholders tend to be reluctant to purchase insurance from insurers with lower solvency.[28] Therefore, we do not have prior expectation on how financial leverage impacts loss ratio, combined ratio, and underwriting profitability, respectively.[29]

Liquidity

It is defined as the ratio of liquid assets to total admitted assets (Pooser and Browne, 2018). Managers of insurers with high liquidity tend to signal sound financial condition and better claims-paying ability to prospective policyholders (Adams, Burton, and Hardwick, 2003). Specifically, since customers concern whether insurers are healthier or not (Froot, 2007), thus, many new businesses are underwritten by liquid insurers.[30] However, risk averse insurer managers have the tendency to maintain high extent liquidity and adopt low-risk underwriting strategies to mitigate the insolvency risk concerns, indicating that less new businesses are generated. Therefore, we do not have prior expectations on how liquidity influences loss ratio, combined ratio, and underwriting profitability, respectively.

Firm age

We measure firm age as the value of the natural logarithm of the number of years since the insurer was founded (Pooser and Brown, 2018). Older insurers have

[27] For highly levered insurers, they are prone to suffer from the adverse effects resulting from the variations in underwriting performance and economic shock. Specifically, their capability meeting commitments made to policyholders decreases with a rise of leverage (Adams, Burton, and Hardwick, 2003).

[28] Policyholders purchase insurance with insurers with better solvency and 'shy away' insurers with high leverage after screening the insurer's fundamental information to avoid possible occurrence of bankruptcy event and to preserve the right of their financial claim in the future (Adams, Upreti, and Chen, 2019).

[29] Specifically, we do not have expectations on whether financial leverage increases or decreases new business.

[30] Highly liquidity equips insurer managers to handle the unexpected or emergent cash demands as a result of the short-term contractual characteristics of property and liability policy (Chang and Jeng, 2016).

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competitive advantages, in terms of specific knowledge or underwriting techniques, over relatively young counterparts. These advantages result from rooted insurance distribution networks, a long-accumulated customer-base, and acquired product-market knowledge (Giroud and Mueller, 2010). Hence, we expect that older insurers underwrite more less risky new business compared to younger insurers. Specifically, we expect that firm age decreases loss ratio and combined ratio but increases underwriting profit.

Stock form

Since two dominant types of insurers exists in the insurance industry. Specifically, both stock and mutual type insurers have respective product pricing, agency problem, risk-taking, and profit motives (Lamm-Tennant and Starks, 1993; Cummins et al., 1999). Thus, an organizational form variable ($Stock\_form$) is included as one of the control variables.[31] We define the organizational form variable as a dummy variable, 1 for stock insurers and 0 for mutual insurers (Pooser and Brown, 2018). For stock type insurer managers, they have more access to capital market, and, therefore, grow faster than mutual insurers do in terms of new businesses.[32] Specifically, they have the ability and underwriting capacity to adopt risky underwriting strategies and underwriting more new businesses. Therefore, we expect that organization form variable ($Stock\_form$) is positive associated with loss ratio, combined ratio, and underwriting profitability.

Premium growth

Premium growth is defined as the difference in direct premiums written from year t to year t−1 divided by direct premiums written in year t-1 (Pooser and Brown, 2018). Higher premium growth may suggest that insurers adopt aggressive underwriting strategies to grow their business (Yan, 2013). Specifically, high premium growth may be due to the low level of underwriting standards and underpricing strategies (Adams et al., 2003). However, insurers may concentrate on less risky business and adopt measures to retain existing less risky old policyholders since they may confront with agency problems resulting from high level of debt (Frank and Goyal, 2009). Therefore,

[31] A stock insurer is owned by shareholders and a mutual insurer is owned by policyholders.
[32] To maximize shareholders' short-term wealth, managers of stock insurers tends to engage in risky activities (Adams, 1995). However, due to limited access to external capital market, mutual insures grow slower than stock insurers do in underwriting (Powell et al., 2008).

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we do not make prior expectations on how premium growth impacts loss ratio, combined ratio, and underwriting profitability.

Reinsurance

Reinsurance is defined as the ratio of reinsurance ceded to gross premium written (Shiu, 2011).[33] Reinsurance mitigates not only underwriting risks and insolvency concerns but also further equips cedants to enhance their underwriting capacity (Mankay and Belgacem, 2016). Moreover, reinsurers not only afford underwriting expertise and specific information for cedants to grow new business (Anand, Leverty and Wunder, 2020), making less expense incurred, but also monitor the underwriting activities of cedants (Doherty and Smetters, 2005), leading insurers to adopt appropriate underwriting strategies. Therefore, we also do not make prior expectations regarding how reinsurance affects loss ratio, combined ratio, and underwriting profitability.

RBC ratio

RBC ratio, measuring an insurer's capital relative to the overall riskiness of operating (Hendershott et al., 2020), is defined as total adjusted capital divided by the authorized control-level (Pooser and Browne, 2018). Specifically, insurers with higher RBC ratio are better capitalized and thus have higher underwriting capacity to underwrite new business, resulting in higher loss ratio, combined ratio, and underwriting profitability. On contrary, managers of insurers with higher RBC ratio may be risk-averse, indicating that managers tend to adopt conservative underwriting strategy. Therefore, we do not have prior expectations on the effects of RBC ratio on loss ratio, combined ratio, and underwriting profitability.

3.3 Regression models

This section introduces the empirical regression models used in this study and how to estimate the effects of the tenure of insurer-reinsurer relationship on insurers' underwriting profitability. The empirical regression model is listed as follows.

$$UW\_profit_{i,t} = \beta_0 + \beta_1 \cdot Reins\_sus_{i,t-1} + \beta_2 \cdot Reins\_sus^2_{i,t-1} + \beta' \cdot CV_{i,t-1} + \varepsilon_{i,t}$$

[33] Reinsurance ceded is the summation of affiliated reinsurance ceded and non-affiliated reinsurance ceded. Additionally, premium written is the summation of direct business written and reinsurance assumed.

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(1)

$UW\_profit_{i,t}$ denotes the primary insurer's underwriting profitability, including loss ratio, combined ratio, and underwriting profitability, respectively. $Reins\_sus_{i,t-1}$ indicates the tenure of insurer-reinsurer relationship for insurer i at time t-1. Specifically, we use four reinsurance sustainability measures, including $Reins\_sus\_total_{i,t-1}$, $Reins\_sus\_p25_{i,t-1}$, $Reins\_sus\_p50_{i,t-1}$, and $Reins\_sus\_p75_{i,t-1}$. $Reins\_sus^2_{i,t-1}$ denotes the squared term of reinsurance sustainability for insurer i at time t-1, including $Reins\_Sus\_total^2_{i,t-1}$, $Reins\_Sus\_p25^2_{i,t-1}$, $Reins\_Sus\_p50^2_{i,t-1}$, and $Reins\_Sus\_p75^2_{i,t-1}$. $CV_{i,t-1}$ denotes the control variables, including $Firm\_size_{i,t-1}$, $Fin\_lev_{i,t-1}$, $Liquid_{i,t-1}$, $Firm\_age_{i,t-1}$, $Stock\_form_{i,t-1}$, $Pre\_growth_{i,t-1}$, $Reins_{i,t-1}$, $RBC\_ratio_{i,t-1}$. $\varepsilon_{i,t}$ is the residual term of equation (1). β_0 is an intercept term. β_1 and β_2 capture the non-linear effects of reinsurance sustainability on insurer's underwriting profitability. β denotes the vector capturing the effects of control variables on insurer's underwriting profitability.

We specify a lead-lagged relationship to avoid potential simultaneous causality problem (Andreou, Andreou, and Lambertides, 2021). Specifically, all independent variables are suggested to be lagged by 1-year to alleviate the endogeneity concerns (Géczy, Minton, and Schrand, 1997). Since we include lagged dependent variables as our independent variables, we must be aware of dynamic panel bias. Specifically, such bias is characterized by the association of lagged dependent variables and the errors. To solve the bias, autoregressive dynamic panel data models are used in estimating the estimators. Specifically, we use one-step GMM-system and one-step GMM-difference models to alleviate such bias. The former was developed by Blundell and Bond (1998) and the latter was developed Arellano and Bond (1991). In addition, we specify robust standard errors for GMM-system model and WC-robust for GMM-difference model (Wooldridge, 2016). All variables, excluding dummy variables, are winsorized at the 1 percent level to remove outliers (Lin et al., 2011).

4. Empirical results

4.1 Summary statistics and Univariate analysis

The summary statistics of the dependent variables and independent variables used in our full sample analysis are shown in Table 2. All results are based on firm-year analysis.

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From 2013 to 2020, regarding dependent variables, the mean value of loss ratio is 0.65910 and the value of standard deviation is 0.24557, consistent with Chang (2019).[34] Combined ratio shows 0.88228, average value, and 0.31469, standard deviation. Finally, the mean value of underwriting profitability is 0.11771 and the corresponding standard deviation is 0.31469. All dependent values are seemed to be within appropriate range.

<Table 2 is inserted here>

Regarding main independent variables, the average value of $Reins\_Sus\_total_{i,t-1}$, $Reins\_Sus\_p25_{i,t-1}$, $Reins\_Sus\_p50_{i,t-1}$ and $Reins\_Sus\_p75_{i,t-1}$ are 1.52072, 1.60253, 1.91685, and 2.27919, respectively.[35] These values indicate that insurers with larger amount of reinsurance premium ceded in past 5 years, considered to be relatively important reinsurance relationship, tend to have longer reinsurance relationship. In addition, the minimum value and maximum value of the four reinsurance sustainability measures are within the range of 0 to 5, indicating value range of reinsurance sustainability and their squared term are modest. The mean values of control variables and other statistics are as expected and thus are reasonable. Taken together, our preliminary statistics suggests that all variable data are modest after the adoption of elimination of illogical observations.

To further test whether multicollinearity problem exists, we compute the variance inflation factor (VIF) for independent variables. Except for the reinsurance sustainability and the squared term of reinsurance sustainability, the VIF values for all independent variables are under 10, well below the rule of thumb cutoff point of 10 for multiple regression models (Kennedy, 1998). To alleviate potential multicollinearity problem, we mean center the four reinsurance sustainability variables, $Reins\_Sus\_total_{i,t-1}$, $Reins\_Sus\_p25_{i,t-1}$, $Reins\_Sus\_p50_{i,t-1}$ and $Reins\_Sus\_p75_{i,t-1}$, respectively.

Table 3 documents the Pearson correlation matrix to capture the simple correlation coefficients on the all variables used in this study. Regarding the four reinsurance sustainability variables, overall, reinsurance sustainability is negatively and significantly, at least 10% significant level, associated with loss ratio and combined ratio. Additionally, the squared terms of the four reinsurance sustainability variables are

[34] In Chang (2019)'s study, the average of loss ratio is 0.6228 and the standard deviation of that is 0.2695.

[35] The values of mean and standard deviation of reinsurance sustainability variable in Garven et al. (2014) are 1.716 and 1.394, respectively.

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also significantly associated with loss ratio and combined ratio, respectively, providing primary support for hypothesis 1 and 2. In addition, reinsurance sustainability variables are positively and significantly associated with underwriting profitability and the squared term of combined ratio at 1% significant level, also providing primary evidences supporting hypothesis 3.

<Table 3 is inserted here>

Concerning control variables, we find that firm size is positively correlated with loss ratio and underwriting profitability at 1% level and negatively correlated with combined ratio at least 5% significance. It provides primary supports for the notion that larger firms have more underwriting capacity and risk tolerance to undertake riskier business, and they tend to operate efficiently. Financial leverage is positively correlated with loss ratio and combined ratio but negatively correlated with underwriting profitability, indicating that highly levered insurers adopt aggressive underwriting strategies by reducing the standard of risk assessment and their insurance price (Adams, Upreti, and Chen, 2019) resulting in poor underwriting experience. Liquidity is negative associated with loss ratio and combined ratio at 1% significant level but positively associated with underwriting profitability, indicating that risk-aversion managers tends to take less risky underwriting strategies. Firm age is negatively correlated with loss ratio and combined ratio but positively correlated with underwriting capacity. The evidence providing primary support for the denote that firm with longer operating history accumulate better underwriting expertise. Stock form is negatively correlated with combined ratio at 1% significant level, providing primary support that stock insurers subject to higher level of monitoring from stockholders, and thus have better underwriting profitability. Premium growth is positively correlated with loss ratio and combined ratio at 1% significant level but negatively correlated with underwriting profitability, providing primary support that insurers may lower the underwriting standard to increase insurance income. Reinsurance is positively associated with loss ratio and underwriting profitability but negatively associated with combined ratio, providing primary support for the notion that reinsurers provide real service, professional expertise and specialized knowledge, for cedants to expand their business. RBC ratio is negatively correlated with loss ratio, providing primary supports showing that financially sound insurers tend to underwrite more less risky business.

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4.2 Information asymmetry testing in reinsurance contracting behavior

Information asymmetry is a major problem in contract theory. Such related issues start from Rothschild and Stiglitz (1976). Full insurance may not be optimal for insurance underwriters, causing information related problems, such as both adverse selection, advantageous selection, and moral hazard. Their theory indicate that various contract designs only could partially mitigate such concerns and could not reach the first best result due to the unavailability to fulfill the customers demand. Specifically, the customers could only purchase the amount of coverage less than that they desired. Based on the model of Jean-Baptiste and Santomero (2000), the phenomenon of learning over time by reinsurers may induce cedants to take measures, including invest in loss prevention or mitigation, to improve loss experience. Specifically, reinsurance and loss ratio may be related. Thus, we perform standard test regarding information asymmetry in reinsurance market. Specifically, we examine whether reinsurance level and actual incurred claim experience is associated with each other. We follow the approach conducted by Garven et al. (2014) in time-series context. Specifically, we perform the time series tests to see whether information asymmetry exists.

First, we follow the standard approach for testing information asymmetry by specifying two regression models, including reinsurance model and loss ratio model (Yan and Hong, 2015; Chen and Shiu, 2020a). In addition, the control variables included in this analysis are the same as those used in the following chapters. Next, we estimate the residuals of the two regression models and then we multiply them for each observation. The reason behind such method is that we believe information asymmetry still exists between insurers and reinsurers (in other words, information asymmetry phenomena are not mitigated by asymmetric learning or other independent variables) if the residuals from the two models change in the same directions consistently. Specifically, the extent of reinsurance and underwriting risk taking both are determined jointly. On the contrary, the results from the residuals suggest that reinsurance may include the revealed information from the insurers into reinsurance pricing and adjust the reinsurance premiums corresponding to the risk type of ceded business through learning underwriting information over time. Next, we must determine whether the residuals of the two models move in the same direction or divergently by multiplying the residual from the two models for each observation. If the value of the product is

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positive, when the residuals from the two models are both positive or negative simultaneously. On the contrary, reinsurance coverage and underwriting risk are not jointly determined when the value of the product is negative, indicating that information asymmetry is not a major concern.

Regarding the information asymmetry tests, we perform two types of tests. Firstly, t-test is conducted to examine whether the product calculated from the residuals is different from zero significantly. To be more precisely, the null hypothesis denotes that information asymmetry exists, indicating that the average value of the product of residuals shows positive and significant. In contrast, the alternative hypothesis denotes that the average value of the product presents non-positive, suggesting that the level of information asymmetry has been reduced.

Panel A of Table 4 presents the results of t-test for analyzing the product of the residuals. We use $Reins\_sus\_p50_{i,t-1}$ as our reinsurance sustainability measure. The t-test statistic shows negative, denoting that the residuals from the two models have more observations showing opposite signs than those presenting similar signs. It may provide evidences supporting the alternative hypothesis. However, such relationship may be non-linear and not be completely captured by t-test. Therefore, we further perform our second test.

Second, we follow Garven et al. (2014) and perform our second tests by utilizing regression analysis. Specifically, we specify the product of residuals from the reinsurance and loss ratio models as our dependent variable. Different from Garven et al. (2014), we specify reinsurance sustainability, $Reins\_sus\_p50_{i,t-1}$ and $Reins\_Sus\_p50^2_{i,t-1}$ as our independent variables to capture non-linear relationship. In addition, we include a variable, Year trend_t, capturing time trend in our independent variable setting.

Panel B of Table 4 documents the results of regression analysis on information asymmetry testing when using the product of the residuals as dependent variables. The results further show that reinsurance sustainability, $Reins\_Sus\_p50_{i,t-1}$, is inverted U-shaped related to the product of the residuals. Specifically, $Reins\_sus\_p50_{i,t-1}$ and $Reins\_Sus\_p50^2_{i,t-1}$ are positively and negatively associated with the product of residuals, respectively, at convention significant level. The results do not reject and do reject the hull hypothesis at low and high levels of reinsurance sustainability, respectively. The results are inconsistent with Garven et al. (2014) and Yan and Hong

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(2015). Based on the Lind and Mehlum (2010)'s three-step procedure, the related inverted-U tests are confirmed by the following checking step. First, the coefficients of $Reins\_sus\_p50_{i,t-1}$ and $Reins\_Sus\_p50^{2}_{i,t-1}$ are positive and negative significant, respectively. Second, the slope is positive and significant at the low end of the reinsurance sustainability range but negative and significant at the high end of such range. Third, the turning point is 3.14507 and the confidence interval, estimated by Delta method (Lind and Mehlum, 2010), of that turning point ranges from 2.63624 to 3.65390. They are both within the reinsurance sustainability data range, from 0 to 5. Specifically, information asymmetry exists when the level of reinsurance sustainability is low but is mitigated as the level of reinsurance sustainability is high.

4.3 Multivariate analysis

The regression results of reinsurance sustainability on loss ratio, combined ratio, and underwriting profitability are presented in Table 5, 6, 7, 8, 9, and 10, respectively.

<Table 5, 6, 7, 8, 9, and 10 are inserted here>

Table 5, 6, 7, 8, 9, and 10 present the relevant test statistics. All λ^2 values for testing whether the statistics are significant for the overall goodness of fits, showing statistically significant. Thus, it is confirmed that the fitted model is better than a null model without explanatory variables. The total number of firm-year observation when using one-step GMM-system model is 8,544 in Table 4, 6, and 8 and when using one-step GMM-difference model is 7,060 in Table 5, 7, and 9. The former analysis includes 1,426 number of insurers and the latter analysis includes 1,304 number of insurers.
Concerning the empirical results by using one-step GMM-system and GMM-difference models in Table 4, 5, 6, 7, 8, and 9, the statistics of AR(1) and AR(2) are significant except for some conditions of underwriting profitability, providing support for the notion that 1-year lagged and 2-year lagged loss ratios, combined ratio, and underwriting profitability are appropriate in our independent variables specification. Lind and Mehlum (2010) propose a three-step procedure to provide evidence whether complex inverted U-shaped relationship exist.[36] First, significant and positive coefficients of reinsurance sustainability and significant and negative coefficients of the

[36] I utilize STATA 12.0 to conduct "utest" commands to not only perform Sasabuchi-test but also investigate whether the slopes are significantly different from zero at both ends of data range. Specifically, this command examines whether the relationships between the main independent variables and dependent variables are (inverse) U-shaped relationship.

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squared term of reinsurance sustainability indicate inverted U-shaped relationship in Table 4, 5, 6, and 7. In addition, significant and negative coefficients of reinsurance sustainability and significant and positive coefficients of the squared term of reinsurance sustainability indicate inverted U-shaped relationship in Table 8 and 9. Second, the slopes must be sufficiently steep at both ends of data range. 0 is at the low end of reinsurance sustainability range, and 5 is at the high end of reinsurance sustainability range. The slopes at the low end of reinsurance sustainability ranges from 0.012 to 0.027 and show significance. In addition, the slopes at the high end of reinsurance sustainability ranges from -0.029 to -0.012 and present significance. These results indicate inverted U-shaped relationships exist in Table 4, 5, 6, and 7. Regarding underwriting profitability, the slopes at the low end of reinsurance sustainability ranges from -0.026 to 0.013 and show significance. In addition, the slopes at the high end of reinsurance sustainability ranges from 0.011 to 0.013 and present significance. Third, the turning point of the inverted U-shaped relationships need to be located within the data range. Taking the first derivative of Equation 1 with respective to reinsurance sustainability and setting it to zero. Specifically, the values of turning point ranges are all within the data range.[37] According to the statistics of Sasabuchi-test, all of values of the statistic present significance at least 5% level. Next, we estimate the extreme point of effect of reinsurance sustainability and calculated confidence intervals based on the Delta method. The confidence intervals for the Delta method in table 4, 5, 6, 7, and 8 denote that the reinsurance sustainability values are within the limits of the data.

In figure 1, we follow the plotting approach of Farah et al. (2021) and plot three curves, including the tenure of insurer-reinsurer relationship-loss ratio curve, the tenure of insurer-reinsurer relationship-combined ratio curve, and the tenure of insurer-reinsurer relationship-underwriting profitability curve by specifying other independent variable fixed at their respectively mean values and by specifying $Reins\_Sus\_p50_{i,t-1}$ as reinsurance sustainability measure and using one-step GMM-system model. We find that loss ratio increases when the tenure of insurer-reinsurer relationship is lower than 2.726, but lowers when such relation's duration is higher than 2.726. Combined ratio rises when the tenure of insurer-reinsurer relationship is lower than 2.651, but lowers when such relation's duration is higher than 2.651. Finally, underwriting profitability lowers when the tenure of insurer-reinsurer relationship is lower than 3.489, but lowers

[37] The values of turning points of all situations range from 2.627 to 3.690.

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when such relation's duration is higher than 3.489. Combine results mentioned above, we can conclude that reinsurance sustainability is complex inverted U-shape related to loss ratio and combined ratio but is complex U-shaped related to underwriting profitability, consistent with hypothesis 1, 2, and 3.

<Figure 1 is inserted here>

The results indicate that the level of information asymmetry is higher when the tenure of insurer-reinsurer relationship is low but is lower when such relation's duration is low. Specifically, insurers become more aggressive and adopt aggressive underwriting strategies to grow more new business since information asymmetry is high. On the contrary, insurers would adopt less risky underwriting strategies and put more efforts in risk classification, control and mitigation and to improve loss experience for renewing and purchasing reinsurance at a lower price in the future and be subject to higher level of monitoring by reinsurers. Moreover, the reinsurer would take measures to retain more existing policyholders and underwrite less new business. In addition, reinsurers provide advices on underwriting and claim handling to assist insurers to mitigate adverse selection and moral hazard in insurance market, resulting in lower loss ratio, combined ratio, and higher underwriting profitability. In sum, reinsurance sustainability decreases loss ratio and combined ratio but increases underwriting profitability when the level of the tenure of insurer-reinsurer relationship is longer. Overall, these results are not consistent with Cohen (2012) and Shi and Zhang (2016). In addition, they are also consistent with the notion of risk mitigation benefits in relationship banking literature (Boot, 2000), indicating that banks generate specific, durable and reusable information and thus the borrower risk is lower. The reason why the effects differ across different levels of reinsurance sustainability may be that insurers are professional underwriters and they could adjust their risk but policyholders have no incentives to increase their own risk exposure. However, this study provides indirect evidences supporting the notion that financial performance improves as the reinsurance relationship lengthens on average (Garven et al., 2014). In addition, our evidences are also indirectly consistent with the notion that relationship banking reduce information asymmetry between banks and lenders (Donker, Ng, and Shao, 2020).

Regarding the control variables, 1-year and 2-year lagged loss ratio, combined ratio, and underwriting profitability are significantly and negatively associated with current loss ratio, combined ratio, and underwriting profitability, respectively, inconsistent with

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results of Adams, Upreti, and Chen (2019). The results do not support the notion that underwriting cycle exists. Firm size is positively associated with combined ratio when using one-step GMM-system model, but is negatively associated with underwriting profitability, indicating that larger firms have higher underwriting capacity to underwrite riskier business but the loss experience is poor. These results are not consistent the Cummins and Zi (1998) indicating that larger firms have higher operational efficiencies. Financial leverage is negatively associated with combined ratio but is positively associated with underwriting profitability. The results indicate that highly levered insurers devote more resources efforts and resources in improving underwriting efficiency and loss prevention and mitigation activities. Therefore, underwriting profitability is higher. Firm age is positive correlated with combined ratio at 10% significant level when using one-step GMM-difference model but is negatively associated with underwriting profitability. The results indicate that firms with longer past operating experience accumulate more mature underwriting techniques. Older insurers have more comparative advantages compared to younger opponents in terms of an existing customer-base and product-market knowledge and underwrite more less risky business. However, such firms do not operate efficiently. Stock form is positively associated with loss ratio when using one-step GMM-system model. The results indicate that stock form insurers may have access to capital market and adopt risky underwriting strategies and grow more new businesses. Premium growth is found to be significantly and negatively correlated with combined ratio, indicating that insurers may concentrate on underwriting the less risky business and retain more existing less risky policyholders. Reinsurance is positively associated with loss ratio in table 4 and 5, providing evidences supporting the notion that insurers purchasing reinsurance have higher underwriting capacity and thus underwriting more riskier business. Reinsurers could provide real service to assist insurers in enhancing underwriting efficiency (Anand et al., 2020). RBC ratio is negatively correlated with underwriting profitability when using one-step GMM-system model, indicating that holding higher capital buffer makes insurers unprofitable.

4.4 Reverse causality testing

In the beginning, we specify a lead-lag relationship between dependent variable in time t and independent variable in time t-1 to avoid reverse causality problem. Specifically,

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we specify four reinsurance sustainability measured in year t-1 and use them to estimate loss ratio, combined ratio, and underwriting profitability in the subsequent year t. We intend to follow Andreou et al. (2021) to further examine whether dynamic reverse causality exists by swapping the main variables of interest. In the next stage, we further conduct analysis by examining whether loss ratio, combined ratio, and underwriting profitability in year t-1 are correlated with four types of reinsurance sustainability in year t by using the one-step GMM-system model.

Table 11 presents the results of dynamic reverse causality testing. Panel A, B, and C of Table 11 presents that loss ratio, combined ratio, and underwriting profitability in year t-1 is not associated with the reinsurance sustainability measures in year t, respectively. Based on the results of three panels, overall, reinsurance sustainability-loss ratio, reinsurance sustainability-combined ratio, and reinsurance sustainability-underwriting profitability relationships are not impacted by the concerns of dynamic reverse causality.

<Table 11 is inserted here>

5. Conclusions

This study sets out to examine whether the tenure of insurer-reinsurer relationship is related to primary insurer's underwriting profitability by using NAIC data covering the year from 2013 to 2020 on a sample of US property-casualty insurers. We find that the tenure of insurer-reinsurer relationship is inverted U-shaped associated to insurer's loss ratio and combined ratio. In addition, the results also document that the tenure of insurer-reinsurer relationship is U-shaped related to underwriting profitability. These results are consistent with asymmetric learning hypothesis, indicating that the level of information asymmetry is higher when the level of tenure of insurer-reinsurer relationship is low but the level of information asymmetry gradually decreases as the level of relation's duration increases. Managers of insurers with shorter tenure tend to put less efforts in underwriting and risk classification and thus they tend to switch their ceded businesses to other reinsurers to fleet their poor underwriting experience. Thus, insurers' loss ratio and combined ratio increases but their underwriting profitability decreases as they renew reinsurance. However, managers of insurers may put more efforts in underwriting since the function of monitoring by incumbent reinsurers is high due the revelation of past underwriting experience. Therefore, loss ratio and combined

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ratio decreases but underwriting profitability increases as the tenure of insurer-reinsurer relationship increases.

Our findings have several implications. It is considered in practice that reinsurance markets relies on long-term relationship between reinsurers and primary insurers. How long-term reinsurance contracting relationship affect underwriting profitability is an interesting question. This study provides empirical evidences to support the notion that insurers purchase reinsurance as a strategic tool to enhance their competitiveness. However, when the level of the tenure is high, managers tend to take conservative underwriting strategies to maintain the long-term relationship with reinsurers for purchasing reinsurance at a lower reinsurance premiums (prices). This study provides evidence showing how maintaining long-term relationship affects the insurer's underwriting profit to advance the information asymmetry literature to the strategic dimension. This study additionally provides another consider considering the reinsurance sustainability measure and the amount of reinsurance premium for future research to improve.

These results may indicate that maintaining long-term relationship with incumbent reinsurers may provide benefits for insurers, policyholders, and regulators. Those insurers renewing reinsurance for a long time may be low-risk type insurers. It may encourage insurers to renew the reinsurance to improve their underwriting experience when the level of the tenure of insurer-reinsurer relationship is high due to high level of monitoring by reinsurers. Therefore, this study enables policymakers to improve regulations on a basis of long-term relationship features.

In addition, this study may provide another aspect for explaining the findings of Chang (2019) of why reinsurance could not enhance market share since the cost of reinsurance and the function of monitoring by reinsurers differs across various levels of the tenure of insurer-reinsurer relationship. In addition, this study may also provide other empirical results supporting that why the effects of reinsurance on performance may not be consistent in the reinsurance literature.

The limitation of research is that we could only attain the total business reinsurance relationship since the NAIC dataset only provide the data of total business reinsurance transaction information in Schedule F part 3. Specifically, we have no access to the data regarding the reinsurance relationship of different types of reinsurance contract or

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business lines.[38] Thus, we are unable to further investigate the effects of different types of reinsurance relationship duration on various loss ratio of business lines and compare the impacts whether such effects are pronounced for commercial or health business lines than those of individual lines.

Future research could focus on how the long-term relationship in reinsurance market affects the usage of other risk-linked instruments, such as financial derivatives. However, risk management incurs costs. In addition, managers determine the overall risk exposure, including underwriting and investment risk exposure, when making risk management decisions. Insurers with high tenure could transfer more underwriting risk at a lower cost due to the mitigation of adverse selection. Therefore, it is interesting to investigate whether the tenure of insurer-reinsurer relationship affects the usage of financial derivatives in the future.

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[38] For example, we could not acquire the data of reinsurance sustainability regarding proportional reinsurance, non-proportional reinsurance or facultative reinsurance. In addition, we have no access to the data to calculate the value of reinsurance sustainability regarding auto line, commercial line, or personal business line.

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Table 1: Variable names and definitions

Variables	Definitions
Dependent variable	
$Loss\_ratio_{i,t}$	It is the ratio of loss and loss adjustment expenses divided by premium earned.
$Combined\_ratio_{i,t}$	It is defined as the summation of expense ratio at time t and loss ratio at time t.
$UW\_profit_{i,t}$	It is defined as 1 minus combined ratio at time t.
Independent variable	
$Loss\_ratio_{i,t-1}$	It is 1-year lagged loss ratio.
$Loss\ \_ratio_{i,t-2}$	It is 2-year lagged loss ratio.
$Combined\_ratio_{i,t-1}$	It is 1-year lagged combined ratio.
$Combined\_ratio_{i,t-2}$	It is 2-year lagged combined ratio.
UW_profit_{t-1}	It is 1-year lagged underwriting profitability.
UW_profit_{t-2}	It is 2-year lagged underwriting profitability.
$Reins\_Sus\_total_{i,t-1}$	A measure of reinsurance sustainability. It is defined as the ratio of the mean value of the reinsurance relationship count distribution divided by the standard deviation of the reinsurance relationship count distribution plus 1. In addition, this variable is calculated by including all reinsurance relationship transactions.
$Reins\_Sus\_total_{i,t-1}^2$	It is a squared term of reinsurance sustainability, $Reins\_Sus\_total_{i,t-1}$.
$Reins\_Sus\_p25_{i,t-1}$	A measure of reinsurance sustainability. It is defined as the ratio of the mean value of the reinsurance relationship count distribution divided by the standard deviation of the reinsurance relationship count distribution plus 1. In addition, this variable is calculated by including the reinsurance relationship transactions whose values are larger than the value of 25th percentile of all reinsurance relationships.
$Reins\_Sus\_p25_{i,t-1}^2$	It is a squared term of reinsurance sustainability, $Reins\_Sus\_p25_{i,t-1}$.
$Reins\_Sus\_p50_{i,t-1}$	A measure of reinsurance sustainability. It is defined as the ratio of the mean value of the reinsurance relationship count distribution divided by the standard deviation of the reinsurance relationship count distribution plus 1. In addition, this variable is calculated by including the reinsurance relationship transactions whose values are larger than the value of 50th percentile of all reinsurance relationships.
$Reins\_Sus\_p50_{i,t-1}^2$	It is a squared term of reinsurance sustainability, $Reins\_Sus\_p50_{i,t-1}$.

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$Reins\_Sus\_p75_{i,t-1}$	A measure of reinsurance sustainability. It is defined as the ratio of the mean value of the reinsurance relationship count distribution divided by the standard deviation of the reinsurance relationship count distribution plus 1. In addition, this variable is calculated by including the reinsurance relationship transactions whose values are larger than the value of 75th percentile of all reinsurance relationships.
$Reins\_Sus\_p75^2_{i,t-1}$	It is a squared term of reinsurance sustainability, $Reins\_Sus\_p75_{i,t-1}$.
$Firm\_size_{i,t-1}$	It is defined as the natural logarithm of total net admitted asset.
$Fin\_lev_{i,t-1}$	It is defined as the ratio of total liabilities divided by total net admitted assets.
$Liquid_{i,t-1}$	It is defined as the ratio of liquid assets to total assets.
$Firm\_age_{i,t-1}$	It is defined as the natural logarithm of the firm's age in years.
$Stock\_form_{i,t-1}$	It is a dummy variable that equals one for stock insurers and zero for mutual insurers.
$Pre\_growth_{i,t-1}$	It is the ratio of the difference in direct premiums written from time t to t−1 divided by direct premiums written in time t-1.
$Reins_{i,t-1}$	It is defined as the ratio of affiliated reinsurance ceded plus non-affiliated reinsurance ceded divided by direct business written plus reinsurance assumed.
$RBC\_ratio_{i,t-1}$	It is the ratio of total adjusted capital divided by the authorized control-level risk-based capital.

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Table 2: Descriptive analysis

Variables	Mean	S.D.	Min	25^{th}	Median	75^{th}	Max	Obs
Dependent variable								
$Loss\_ratio_{i,t}$	0.65910	0.24557	0.00049	0.55311	0.66858	0.75745	2.59354	12,500
$Combined\_ratio_{i,t}$	0.88228	0.31469	0.24588	0.74830	0.85825	0.96599	4.98188	12,500
UW_profit_t	0.11771	0.31469	-3.98188	0.03400	0.14174	0.25169	0.75411	12,500
Independent variable								
$Loss\_ratio_{i,t-1}$	0.65269	0.22760	0.00049	0.55276	0.66929	0.75393	2.59354	10,644
$Loss\ \_ratio_{i,t-2}$	0.64832	0.22314	0.00049	0.55008	0.66633	0.75218	2.59354	9,049
$Combined\_ratio_{i,t-1}$	0.87011	0.27138	0.24588	0.74779	0.85647	0.96152	4.98188	10,644
$Combined\_ratio_{i,t-2}$	0.86484	0.26415	0.24588	0.74664	0.85352	0.95907	4.98188	9,049
UW_profit_{t-1}	0.12988	0.27138	-3.98188	0.03847	0.14352	0.25220	0.75411	10,644
UW_profit_{t-2}	0.13515	0.26415	-3.98188	0.04092	0.14647	0.25335	0.75411	9,049
$Reins\_Sus\_total_{i,t-1}$	1.52072	1.14177	0.66666	0.92730	1.11604	1.42752	5.00000	10,644
$Reins\_Sus\_total^2_{i,t-1}$	3.61611	6.57568	0.44444	0.85990	1.24555	2.03782	25.00000	10,644
$Reins\_Sus\_p25_{i,t-1}$	1.60253	1.16840	0.67423	0.96102	1.17526	1.54551	5.00000	10,644
$Reins\_Sus\_p25^2_{i,t-1}$	3.93314	6.76479	0.45459	0.92357	1.38124	2.38860	25.00000	10,644
$Reins\_Sus\_p50_{i,t-1}$	1.91685	1.29854	0.69035	1.05662	1.39442	2.01110	5.00000	10,644
$Reins\_Sus\_p50^2_{i,t-1}$	5.36041	7.59778	0.47659	1.11645	1.94443	4.04455	25.00000	10,644
$Reins\_Sus\_p75_{i,t-1}$	2.27919	1.39833	0.72762	1.21471	1.69431	3.00000	5.00000	10,644
$Reins\_Sus\_p75^2_{i,t-1}$	7.14988	8.38344	0.52943	1.47552	2.87071	9.00000	25.00000	10,644

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$Firm\_size_{i,t-1}$	18.68287	1.73960	14.51822	17.40336	18.60358	19.83326	23.23086	10,644
$Fin\_lev_{i,t-1}$	0.54709	0.16890	0.05902	0.44501	0.57097	0.67545	0.87516	10,644
$Liquid_{i,t-1}$	0.11553	0.14357	0.00000	0.02756	0.06299	0.14279	0.87182	10,644
$Firm\_age_{i,t-1}$	3.52102	0.97893	0.00000	2.99573	3.55534	4.21950	5.18738	10,644
$Stock\_form_{i,t-1}$	0.74960	0.43326	0.00000	0.00000	1.00000	1.00000	1.00000	10,644
$Pre\_growth_{i,t-1}$	0.12886	0.45728	-0.56912	-0.01510	0.04842	0.12863	5.41271	10,644
$Reins_{i,t-1}$	0.39877	0.28423	0.00000	0.14636	0.35585	0.63188	0.98154	10,644
$RBC\_ratio_{i,t-1}$	12.33836	13.71898	0.93313	5.51006	8.66373	13.59752	182.542	10,644

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Table 3: Pearson correlation matrix

Panel A

	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)
(a)	-												
(b)	0.741***	-											
(c)	-0.741***	-1.000***	-										
(d)	0.678***	0.457***	-0.457***	-									
(e)	0.592***	0.361***	-0.361***	0.705***	-								
(f)	0.458***	0.624***	-0.624***	0.747***	0.478***	-							
(g)	0.367***	0.532***	-0.532***	0.479***	0.749***	0.659***	-						
(h)	-0.458***	-0.624***	0.624***	-0.747***	-0.478***	-1.000***	-0.659***	-					
(i)	-0.367***	-0.532***	0.532***	-0.479***	-0.749***	-0.659***	-1.000***	0.659***	-				
(j)	-0.019**	-0.067***	0.067***	-0.005	0.011	-0.059***	-0.055***	0.059***	0.055***	-			
(k)	-0.017*	-0.066***	0.066***	-0.002	0.014	-0.057***	-0.053***	0.057***	0.053***	0.987***	-		
(l)	-0.017*	-0.067***	0.067***	-0.002	0.013	-0.059***	-0.054***	0.059***	0.054***	0.972***	0.950***	-	
(m)	-0.014	-0.066***	0.066***	0.002	0.019*	-0.057***	-0.052***	0.057***	0.052***	0.963***	0.968***	0.985***	-
(n)	-0.030***	-0.076***	0.076***	-0.014	-0.003	-0.065***	-0.064***	0.065***	0.064***	0.815***	0.786***	0.842***	0.818***
(o)	-0.025***	-0.076***	0.076***	-0.008	0.005	-0.063***	-0.060***	0.063***	0.060***	0.826***	0.816***	0.849***	0.847***
(p)	-0.052***	-0.078***	0.078***	-0.042***	-0.033***	-0.073***	-0.071***	0.073***	0.071***	0.682***	0.648***	0.709***	0.678***
(q)	-0.049***	-0.079***	0.079***	-0.039***	-0.027***	-0.074***	-0.069***	0.074***	0.069***	0.699***	0.678***	0.724***	0.708***
(r)	0.132***	-0.031***	0.031***	0.126***	0.140***	-0.039***	-0.024**	0.039***	0.024**	-0.018*	-0.025**	-0.016	-0.021**
(s)	0.230***	0.024**	-0.024**	0.254***	0.257***	0.022**	0.030***	-0.022**	-0.030***	0.005	0.005	-0.002	0.000
(t)	-0.099***	-0.016*	0.016*	-0.103***	-0.115***	-0.015	-0.031***	0.015	0.031***	-0.046***	-0.043***	-0.051***	-0.046***
(u)	-0.035***	-0.019*	0.019*	-0.007	-0.003	-0.000	0.014	0.000	-0.014	-0.012	-0.015	-0.002	-0.005

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(v)	0.013	-0.062***	0.062***	0.003	-0.003	-0.077***	-0.085***	0.077***	0.085***	0.075***	0.083***	0.063***	0.074***
(w)	0.060***	0.043***	-0.043***	0.048***	0.029***	0.053***	0.088***	-0.053***	-0.088***	-0.040***	-0.035***	-0.048***	-0.040***
(x)	0.114***	-0.228***	0.228***	0.110***	0.101***	-0.228***	-0.224***	0.228***	0.224***	0.145***	0.150***	0.141***	0.150***
(y)	-0.075***	-0.010	0.010	-0.084***	-0.116***	0.013	-0.034***	-0.013	0.034***	0.092***	0.094***	0.092***	0.095***

Panel B

	(n)	(o)	(p)	(q)	(r)	(s)	(t)	(u)	(v)	(w)	(x)	(y)
(n)	-											
(o)	0.984***	-										
(p)	0.847***	0.820***	-									
(q)	0.847***	0.844***	0.985***	-								
(r)	-0.049***	-0.052***	-0.083***	-0.092***	-							
(s)	-0.027***	-0.020**	-0.066***	-0.061***	0.285***	-						
(t)	-0.036***	-0.031***	-0.042***	-0.033***	-0.362***	-0.116***	-					
(u)	0.013	0.004	0.034***	0.024**	0.237***	-0.118***	-0.252***	-				
(v)	0.037***	0.053***	0.016	0.032***	0.078***	0.195***	0.097***	-0.336***	-			
(w)	-0.065***	-0.054***	-0.086***	-0.074***	-0.100***	-0.039***	0.146***	-0.191***	0.104***	-		
(x)	0.119***	0.131***	0.079***	0.093***	-0.025***	0.105***	0.005	-0.093***	0.260***	0.059***	-	
(y)	0.105***	0.108***	0.142***	0.141***	-0.179***	-0.562***	0.059***	-0.032***	-0.019**	0.038***	0.040***	-

Note: 1.(a) $Loss\_ratio_{i,t}$, (b) $Combined\_ratio_{i,t}$, (c) UW_profit_{t}, (d) $Loss\_ratio_{i,t-1}$, (e) $Loss\_ratio_{i,t-2}$, (f) $Combined\_ratio_{i,t-1}$, (g) $Combined\_ratio_{i,t-2}$, (h) UW_profit_{t-1}, (i) UW_profit_{t-2}, (j) $Reins\_Sus\_total_{i,t-1}$, (k) $Reins\_Sus\_total^{2}_{i,t-1}$, (l) $Reins\_Sus\_p25_{i,t-1}$, (m) $Reins\_Sus\_p25^{2}_{i,t-1}$, (n) $Reins\_Sus\_p50_{i,t-1}$, (o) $Reins\_Sus\_p50^{2}_{i,t-1}$, (p) $Reins\_Sus\_p75_{i,t-1}$, (q) $Reins\_Sus\_p75^{2}_{i,t-1}$, (r) $Firm\_size_{i,t-1}$, (s) $Fin\_lev_{i,t-1}$, (t) $Liquid_{i,t-1}$, (u) $Firm\_age_{i,t-1}$, (v) $Stock\_form_{i,t-1}$, (w) $Pre\_growth_{i,t-1}$, (x) $Reins_{i,t-1}$, (y) $RBC\_ratio_{i,t-1}$.

2. *, **, *** indicates significant level of 0.01, 0.05 and 0.1, respectively.

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Table 4: Tests of information asymmetry

Panel A: t-test				
Reinsurance sustainability	N	Mean	S.D.	t-statistics
$Reins\_Sus\_p50_{i,t-1}$	10,644	-0.00000	0.00000	-0.3577

Panel B: Regression testing		
	Dependent variable Residual (reinsurance) X Residual (loss ratio)	
Variable	Coefficient	S.D.
Constant	3.63e-17	1.43e-16
$Reins\_Sus\_p50_{i,t-1}$	1.91e-18**	7.87e-19
$Reins\_Sus\_p50^2_{i,t-1}$	-3.04-19**	1.34e-19
Year trend_t	-1.90e-20	7.09e-20
N	10,644	
Adjusted R^2	0.0003	
F value (p value)	2.15* (0.09200)	
U-shaped testing		
Sasabuchi-test (p-value)	0.02740**	
Estimated extreme point	3.14507	
Slope (Lower bound)	0.00000***	
Slope (Upper bound)	-0.00000***	
95% (C.I.) -Delta method	(2.63624, 3.65390)	

Note: ***, **, * represent statistical significance at 0.01, 0.05, and 0.1 levels, respectively.

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Table 5: Effects of reinsurance sustainability on loss ratio by using one-step GMM-system model

	Dependent variable: $Loss\_ratio_{i,t}$							
Models	one-step GMM-system model							
Variables	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
$Constant$	0.30143	0.33823	0.30524	0.33777	0.29178	0.33627	0.29257	0.33641
$Loss\ \_ratio_{i,t-1}$	-0.20751***	0.03580	-0.20763***	0.03583	-0.20780***	0.03591	-0.20780***	0.03591
$Loss\_ratio_{i,t-2}$	-0.22401***	0.02985	-0.22406***	0.02986	-0.22373***	0.02984	-0.22373***	0.02984
$Reins\_Sus\_total_{i,t-1}$	0.02807***	0.01088						
$Reins\_Sus\_total^2_{i,t-1}$	-0.00483***	0.00180						
$Reins\_Sus\_p25_{i,t-1}$			0.02458**	0.01051				
$Reins\_Sus\_p25^2_{i,t-1}$			-0.00423**	0.00174				
$Reins\_Sus\_p50_{i,t-1}$					0.02336**	0.00937		
$Reins\_Sus\_p50^2_{i,t-1}$					-0.00429***	0.00164		
$Reins\_Sus\_p75_{i,t-1}$							0.02336**	0.00937
$Reins\_Sus\_p75^2_{i,t-1}$							-0.00429***	0.00164
$Firm\_size_{i,t-1}$	0.02465	0.01676	0.02442	0.01673	0.02502	0.01669	0.02502	0.01669
$Fin\_lev_{i,t-1}$	-0.09529	0.06919	-0.09459	0.06917	-0.09558	0.06926	-0.09558	0.06926
$Liquid_{i,t-1}$	-0.02351	0.04335	-0.02298	0.04337	-0.02180	0.04342	-0.02180	0.04342
$Firm\_age_{i,t-1}$	-0.00282	0.00408	-0.00277	0.00408	-0.00267	0.00410	-0.00267	0.00410
$Stock\_form_{i,t-1}$	0.20629*	0.10568	0.20620*	0.10569	0.20922**	0.10555	0.20922**	0.10555
$Pre\_growth_{i,t-1}$	-0.00154	0.00866	-0.00162	0.00866	-0.00204	0.00867	-0.00204	0.00867
$Reins_{i,t-1},$	0.16911***	0.03464	0.16901***	0.03469	0.16892***	0.03457	0.16892***	0.03457

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$RBC\_ratio_{i,t-1}$	0.00026	0.00080	0.00026	0.00080	0.00027	0.00080	0.00027	0.00080
Obs	8,544		8,544		8,544		8,544	
Number of Firms	1,426		1,426		1,426		1,426	
AR(1)	-8.597***(0.000)		-8.576***(0.000)		-8.5976***(0.000)		-8.597***(0.000)	
AR(2)	3.3786***(0.000)		3.381***(0.000)		3.331***(0.001)		3.331***(0.000)	
λ^2 (p-value)	152.960***(0.000)		152.400***(0.000)		151.570***(0.000)		151.570***(0.000)	
U-shaped testing								
Sasabuchi-test (p-value)	0.011**		0.011**		0.017**		0.039**	
Estimated extreme point	2.903		2.903		2.726		2.703	
Slope (Lower bound)	0.021***		0.018**		0.015**		0.012**	
Slope (Upper bound)	-0.020***		-0.017**		-0.017**		-0.014**	
95% (C.I.) -Delta method	(2.419, 3.386)		(2.280, 3.525)		(2.067, 3.385)		(1.82, 3.585)	

Note: ***, **, * represent statistical significance at 0.01, 0.05, and 0.1 levels, respectively.

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Table 6: Effects of reinsurance sustainability on loss ratio by using one-step GMM-difference model

	Dependent variable: $Loss\_ratio_{i,t}$							
Models	one-step GMM-difference model							
Variables	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
Constant	0.60123*	0.31721	0.61177*	0.31661	0.59586*	0.31818	0.59710*	0.31814
$Loss\ \_ratio_{i,t-1}$	-0.37327***	0.03039	-0.37333***	0.03038	-0.37304***	0.03047	-0.37304***	0.03047
$Loss\_ratio_{i,t-2}$	-0.14806***	0.02242	-0.14831***	0.02242	-0.14806***	0.02245	-0.14806***	0.02245
$Reins\_Sus\_total_{i,t-1}$	0.03049***	0.01028						
$Reins\_Sus\_total^2_{i,t-1}$	-0.00499***	0.00169						
$Reins\_Sus\_p25_{i,t-1}$			0.02500***	0.00950				
$Reins\_Sus\_p25^2_{i,t-1}$			-0.00396**	0.00157				
$Reins\_Sus\_p50_{i,t-1}$					0.02225***	0.00832		
$Reins\_Sus\_p50^2_{i,t-1}$					-0.00381***	0.00148		
$Reins\_Sus\_p75_{i,t-1}$							0.02225***	0.00832
$Reins\_Sus\_p75^2_{i,t-1}$							-0.00381***	0.00148
$Firm\_size_{i,t-1}$	0.02019	0.01720	0.01962	0.01716	0.02033	0.01725	0.02033	0.01725
$Fin\_lev_{i,t-1}$	-0.07967	0.06058	-0.07884	0.06044	-0.07946	0.06055	-0.07946	0.06055
$Liquid_{i,t-1}$	-0.02055	0.03735	-0.01977	0.03736	-0.01904	0.03736	-0.01904	0.03736
$Firm\_age_{i,t-1}$	0.00189	0.00323	0.00189	0.00323	0.00198	0.00326	0.00198	0.00326
$Stock\_form_{i,t-1}$	-0.02814	0.02789	-0.02862	0.02795	-0.02545	0.02808	-0.02545	0.02808
$Pre\_growth_{i,t-1}$	-0.00360	0.00771	-0.00366	0.00772	-0.00415	0.00773	-0.00415	0.00773
$Reins_{i,t-1},$	0.12416***	0.03330	0.12412***	0.03333	0.12382***	0.03318	0.12382***	0.03318

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$RBC\_ratio_{i,t-1}$	0.00084	0.00075	0.00084	0.00075	0.00086	0.00075	0.00086	0.00075
Obs	7,060		7,060		7,060		7,060	
Number of Firms	1,304		1,304		1,304		1,304	
AR(1)	-2.682***(0.007)		-2.674***(0.007)		-2.640***(0.008)		-2.640***(0.008)	
AR(2)	-1.977 **(0.048)		-1.978 **(0.047)		-2.031 **(0.042)		-2.031 **(0.042)	
λ^2 (p-value)	241.600***(0.000)		235.280***(0.000)		248.920***(0.000)		248.920***(0.000)	
U-shaped testing								
Sasabuchi-test (p-value)	0.003***		0.019**		0.033**		0.022**	
Estimated extreme point	3.056		3.157		2.929		2.932	
Slope (Lower bound)	0.023***		0.019***		0.014**		0.013**	
Slope (Upper bound)	-0.019***		-0.014**		-0.013**		-0.012**	
95% (C.I.) -Delta method	(2.600, 3.512)		(2.483, 3.832)		(2.163, 3.696)		(2.108, 3.756)	

Note: ***, **, * represent statistical significance at 0.01, 0.05, and 0.1 levels, respectively.

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Table 7: Effects of reinsurance sustainability on combined ratio by using one-step GMM-system model

	Dependent variable: $Combined\_ratio_{i,t}$							
Models	one-step GMM-system model							
Variables	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
$Constant$	0.61763	0.39438	0.62705	0.39476	0.60120	0.39255	0.60203	0.39276
$Combined\_ratio_{i,t-1}$	-0.20507***	0.04075	-0.20536***	0.04076	-0.20569***	0.04085	-0.20569***	0.04085
$Combined\_ratio_{i,t-2}$	-0.17123***	0.04788	-0.17132***	0.04792	-0.17061***	0.04794	-0.17061***	0.04794
$Reins\_Sus\_total_{i,t-1}$	0.03345***	0.01274						
$Reins\_Sus\_total^2_{i,t-1}$	-0.00579***	0.00208						
$Reins\_Sus\_p25_{i,t-1}$			0.03309***	0.01220				
$Reins\_Sus\_p25^2_{i,t-1}$			-0.00558***	0.00200				
$Reins\_Sus\_p50_{i,t-1}$					0.03328***	0.01089		
$Reins\_Sus\_p50^2_{i,t-1}$					-0.00628***	0.00191		
$Reins\_Sus\_p75_{i,t-1}$							0.03328***	0.01089
$Reins\_Sus\_p75^2_{i,t-1}$							-0.00628***	0.00191
$Firm\_size_{i,t-1}$	0.03486*	0.02006	0.03435*	0.02007	0.03556*	0.02004	0.03556*	0.02004
$Fin\_lev_{i,t-1},$	-0.16285**	0.07895	-0.16192**	0.07893	-0.16394**	0.07900	-0.16394**	0.07900
$Liquid_{i,t-1}$	-0.00507	0.04703	-0.00421	0.04704	-0.00278	0.04705	-0.00278	0.04705
$Firm\_age_{i,t-1}$	0.00296	0.00482	0.00294	0.00482	0.00321	0.00485	0.00321	0.00485
$Stock\_form_{i,t-1}$	-0.05948	0.18875	-0.05985	0.18882	-0.05561	0.18862	-0.05561	0.18862
$Pre\_growth_{i,t-1}$	-0.03651**	0.01453	-0.03646**	0.01454	-0.03715**	0.01459	-0.03715**	0.01459
$Reins_{i,t-1},$	0.04251	0.04284	0.04274	0.04288	0.04248	0.04285	0.04248	0.04285

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$RBC\_ratio_{i,t-1}$	0.00135	0.00104	0.00135	0.00104	0.00136	0.00104	0.00136	0.00104
Obs	8,544		8,544		8,544		8,544	
Number of Firms	1,426		1,426		1,426		1,426	
AR(1)	-7.376***(0.000)		-7.367***(0.000)		-7.377***(0.000)		-7.377***(0.000)	
AR(2)	1.7049 *(0.088)		1.704 *(0.088)		1.659 *(0.097)		1.659 *(0.091)	
λ^2 (p-value)	99.030***(0.000)		97.350***(0.000)		98.860***(0.000)		98.860***(0.000)	
U-shaped testing								
Sasabuchi-test (p-value)	0.005***		0.004***		0.001**		0.015**	
Estimated extreme point	2.890		2.964		2.651		2.627	
Slope (Lower bound)	0.025***		0.025***		0.024***		0.017**	
Slope (Upper bound)	-0.024***		-0.022***		-0.029***		-0.024***	
95% (C.I.) -Delta method	(2.416, 3.365)		(2.434, 3.494)		(2.146, 3.155)		(1.877, 3.377)	

Note: ***, **, * represent statistical significance at 0.01, 0.05, and 0.1 levels, respectively.

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Table 8: Effects of reinsurance sustainability on combined ratio by using one-step GMM-difference model

	Dependent variable: $Combined\_ratio_{i,t}$							
Models	one-step GMM-difference model							
Variables	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
$Constant$	0.78614*	0.40474	0.80472**	0.40435	0.77128*	0.40544	0.77285*	0.40540
$Combined\_ratio_{i,t-1}$	-0.35424***	0.03837	-0.35445***	0.03836	-0.35379***	0.03844	-0.35379***	0.03844
$Combined\_ratio_{i,t-2}$	-0.11727***	0.02724	-0.11752***	0.02723	-0.11656***	0.02728	-0.11656***	0.02728
$Reins\_Sus\_total_{i,t-1}$	0.03474***	0.01165						
$Reins\_Sus\_total^2_{i,t-1}$	-0.00547***	0.00193						
$Reins\_Sus\_p25_{i,t-1}$			0.03147***	0.01073				
$Reins\_Sus\_p25^2_{i,t-1}$			-0.00474***	0.00177				
$Reins\_Sus\_p50_{i,t-1}$					0.02878***	0.00943		
$Reins\_Sus\_p50^2_{i,t-1}$					-0.00495***	0.00168		
$Reins\_Sus\_p75_{i,t-1}$							0.02878***	0.00943
$Reins\_Sus\_p75^2_{i,t-1}$							-0.00495***	0.00168
$Firm\_size_{i,t-1}$	0.02859	0.02218	0.02763	0.02215	0.02919	0.02222	0.02919	0.02222
$Fin\_lev_{i,t-1}$,	-0.17502**	0.07080	-0.17414**	0.07071	-0.17573**	0.07077	-0.17573**	0.07077
$Liquid_{i,t-1}$	-0.01054	0.04028	-0.00948	0.04031	-0.00894	0.04023	-0.00894	0.04023
$Firm\_age_{i,t-1}$	0.00634*	0.00374	0.00628*	0.00374	0.00645*	0.00376	0.00645*	0.00376
$Stock\_form_{i,t-1}$	-0.02526	0.03269	-0.02634	0.03272	-0.02202	0.03294	-0.02202	0.03294
$Pre\_growth_{i,t-1}$	-0.02093	0.01348	-0.02088	0.01349	-0.02168	0.01353	-0.02168	0.01353
$Reins_{i,t-1}$,	0.05627	0.04253	0.05633	0.04256	0.05592	0.04243	0.05592	0.04243

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$RBC\_ratio_{i,t-1}$	0.00077	0.00092	0.00077	0.00092	0.00079	0.00092	0.00079	0.00092
Obs	7,060		7,060		7,060		7,060	
Number of Firms	1,304		1,304		1,304		1,304	
AR(1)	-2.3192 **(0.020)		-2.312 **(0.020)		-2.271 **(0.023)		-2.271 **(0.023)	
AR(2)	-1.7261 *(0.084)		-1.732 *(0.083)		-1.766 *(0.077)		-1.766 *(0.077)	
λ^2 (p-value)	156.250***(0.000)		155.770***(0.000)		159.340***(0.000)		159.340***(0.000)	
U-shaped testing								
Sasabuchi-test (p-value)	0.008***		0.021**		0.006***		0.017**	
Estimated extreme point	3.175		3.319		2.906		2.906	
Slope (Lower bound)	0.027***		0.025***		0.021***		0.016**	
Slope (Upper bound)	-0.019***		-0.015**		-0.020***		-0.015**	
95% (C.I.) -Delta method	(2.692, 3.657)		(2.666, 3.972)		(2.295, 3.517)		(2.110, 3.701)	

Note: ***, **, * represent statistical significance at 0.01, 0.05, and 0.1 levels, respectively.

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Table 9: Effects of reinsurance sustainability on underwriting profitability by using one-step GMM-system model

	Dependent variable: UW_profit_t							
Models	one-step GMM-system model							
Variables	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
Constant	2.71035***	0.51503	2.70157***	0.51476	2.70897***	0.51351	2.70574***	0.51356
$UW\_profit_{i,t-1}$	-0.12558***	0.04273	-0.12631***	0.04278	-0.12563***	0.04273	-0.12563***	0.04273
$UW\_profit_{i,t-2}$	-0.14207***	0.04435	-0.14236***	0.04444	-0.14070***	0.04435	-0.14070***	0.04435
$Reins\_Sus\_total_{i,t-1}$	-0.03260***	0.01271						
$Reins\_Sus\_total^2_{i,t-1}$	0.00442**	0.00211						
$Reins\_Sus\_p25_{i,t-1}$			-0.03265***	0.01201				
$Reins\_Sus\_p25^2_{i,t-1}$			0.00420**	0.00201				
$Reins\_Sus\_p50_{i,t-1}$					-0.03042**	0.01072		
$Reins\_Sus\_p50^2_{i,t-1}$					0.00436***	0.00194		
$Reins\_Sus\_p75_{i,t-1}$							-0.03042***	0.01072
$Reins\_Sus\_p75^2_{i,t-1}$							0.00436**	0.00194
$Firm\_size_{i,t-1}$	-0.14757***	0.02641	-0.14713***	0.02638	-0.14746***	0.02636	-0.14746***	0.02636
$Fin\_lev_{i,t-1},$	0.33256***	0.08402	0.33242***	0.08403	0.33397***	0.08405	0.33397***	0.08405
$Liquid_{i,t-1}$	0.03579	0.04899	0.03469	0.04902	0.03488	0.04906	0.03488	0.04906
$Firm\_age_{i,t-1}$	-0.01505***	0.00494	-0.01488***	0.00493	-0.01498***	0.00497	-0.01498***	0.00497
$Stock\_form_{i,t-1}$	0.18173	0.17969	0.18258	0.17973	0.17926	0.17950	0.17926	0.17950
$Pre\_growth_{i,t-1}$	0.03422**	0.01460	0.03413**	0.01460	0.03470**	0.01459	0.03470**	0.01459
$Reins_{i,t-1},$	-0.01577	0.04415	-0.01622	0.04418	-0.01621	0.04415	-0.01621	0.04415

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$RBC\_ratio_{i,t-1}$	-0.00204*	0.00116	-0.00204*	0.00116	-0.00203*	0.00115	-0.00203*	0.00115
Obs	8,544		8,544		8,544		8,544	
Number of Firms	1,426		1,426		1,426		1,426	
AR(1)	-7.875***(0.000)		-7.866***(0.000)		-7.865***(0.000)		-7.8652***(0.000)	
AR(2)	1.8997 *(0.057)		1.8849 *(0.059)		1.8637 *(0.062)		1.8637 *(0.062)	
λ^2 (p-value)	109.210***(0.000)		109.890***(0.000)		117.110***(0.000)		117.110***(0.000)	
U-shaped testing								
Sasabuchi-test (p-value)	0.100*		N/A		0.085*		N/A	
Estimated extreme point	3.690		3.883		3.489		3.489	
Slope (Lower bound)	-0.026***		-0.040		-0.024***		-0.044	
Slope (Upper bound)	0.011*		-0.004		0.013*		-0.006	
95% (C.I.) -Delta method	(2.757, 4.623)		(2.727, 5.040)		(2.490, 4.488)		(2.490, 4.488)	

Note: ***, **, * represent statistical significance at 0.01, 0.05, and 0.1 levels, respectively.

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Table 10: Effects of reinsurance sustainability on underwriting profitability by using one-step GMM-difference model

	Dependent variable: UW_profit_t							
Models	one-step GMM-difference model							
Variables	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
Constant	3.56506***	0.49663	3.54693***	0.49606	3.56043***	0.49659	3.55698***	0.49651
$UW\_profit_{i,t-1}$	-0.24965	0.04267	-0.25030***	0.04268	-0.24909***	0.04259	-0.24909***	0.04259
$UW\_profit_{i,t-2}$	-0.07718**	0.03259	-0.07769**	0.03262	-0.07602**	0.03254	-0.07602**	0.03254
$Reins\_Sus\_total_{i,t-1}$	-0.03163***	0.01157						
$Reins\_Sus\_total^2_{i,t-1}$	0.00393**	0.00193						
$Reins\_Sus\_p25_{i,t-1}$			-0.02862***	0.01071				
$Reins\_Sus\_p25^2_{i,t-1}$			0.00320**	0.00179				
$Reins\_Sus\_p50_{i,t-1}$					-0.02331**	0.00959		
$Reins\_Sus\_p50^2_{i,t-1}$					0.00279	0.00175		
$Reins\_Sus\_p75_{i,t-1}$							-0.02331**	0.00959
$Reins\_Sus\_p75^2_{i,t-1}$							0.00279	0.00175
$Firm\_size_{i,t-1}$	-0.18849***	0.02677	-0.18757***	0.02673	-0.18822***	0.02676	-0.18822***	0.02676
$Fin\_lev_{i,t-1},$	0.40152***	0.07708	0.40134***	0.07699	0.40222***	0.07713	0.40222***	0.07713
$Liquid_{i,t-1}$	0.03267	0.04189	0.03151	0.04193	0.03257	0.04181	0.03257	0.04181
$Firm\_age_{i,t-1}$	-0.01708***	0.00423	-0.01691***	0.00422	-0.01694***	0.00424	-0.01694***	0.00424
$Stock\_form_{i,t-1}$	0.04984	0.03436	0.05120	0.03447	0.04784	0.03455	0.04784	0.03455
$Pre\_growth_{i,t-1}$	0.01860	0.01320	0.01853	0.01320	0.01921	0.01319	0.01921	0.01319
$Reins_{i,t-1},$	-0.05958	0.04209	-0.05977	0.04210	-0.05961	0.04204	-0.05961	0.04204

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$RBC\_ratio_{i,t-1}$	-0.00140	0.00103	-0.00141	0.00104	-0.00140	0.00103	-0.00140	0.00103
Obs	7,060		7,060		7,060		7,060	
Number of Firms	1,304		1,304		1,304		1,304	
AR(1)	-4.051***(0.000)		-4.0352***(0.000)		-4.019***(0.000)		-4.0198***(0.000)	
AR(2)	-1.017 (0.309)		-1.0403 (0.298)		-1.031 (0.302)		-1.0315 0.3023	
λ^2 (p-value)	166.280***(0.000)		164.880***(0.000)		170.420***(0.000)		170.420***(0.000)	
U-shaped testing								
Sasabuchi-test (p-value)	0.180		N/A		0.299		0.410	
Estimated extreme point	4.023		4.468		4.174		4.556	
Slope (Lower bound)	0.026***		-0.034		-0.019***		-0.013**	
Slope (Upper bound)	0.007		-0.006		0.004		0.001	
95% (C.I.) -Delta method	(2.793, 5.253)		(2.534, 6.401)		(2.032, 6.317)		(1.417, 7.695)	

Note: ***, **, * represent statistical significance at 0.01, 0.05, and 0.1 levels, respectively.

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Table 11: Reverse causality testing

Panel A: loss ratio								
Dependent variable:	$Reins\_Sus\_total_{i,t}$		$Reins\_Sus\_p25_{i,t}$		$Reins\_Sus\_p50_{i,t}$		$Reins\_Sus\_p75_{i,t}$	
Model	one-step GMM-system							
Variables	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
$loss\_ratio_{i,t-1}$	0.01107	0.08771	0.05939	0.08731	-0.05562	0.08813	-0.07162	0.09925
Control variables	Yes		Yes		Yes		Yes	
N	8,544		8,544		8,544		8,544	
Firms	1,426		1,426		1,426		1,426	
λ^2 value (p value)	514.850***(0.000)		565.830***(0.000)		702.88***(0.000)		957.300***(0.000)	

Note: ***, **, * represent statistical significance at 0.01, 0.05, and 0.1 levels, respectively.

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Table 11: Reverse causality testing (continued)

Panel B: combined ratio								
Dependent variable:	$Reins\_Sus\_total_{i,t}$		$Reins\_Sus\_p25_{i,t}$		$Reins\_Sus\_p50_{i,t}$		$Reins\_Sus\_p75_{i,t}$	
Model	one-step GMM-system							
Variables	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
$combined\_ratio_{i,t-1}$	-0.06071	0.07582	-0.02914	0.07460	-0.12267	0.07713	-0.09350	0.09333
Control variables	Yes		Yes		Yes		Yes	
N	8,544		8,544		8,544		8,544	
Firms	1,426		1,426		1,426		1,426	
λ^2 value (p value)	504.51 ***(0.000)		554.43 ***(0.000)		702.21 ***(0.000)		960.41 ***(0.000)	

Note: ***, **, * represent statistical significance at 0.01, 0.05, and 0.1 levels, respectively.

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Table 11: Reverse causality testing (continued)

Panel C: underwriting profitability								
Dependent variable:	$Reins\_Sus\_total_{i,t}$		$Reins\_Sus\_p25_{i,t}$		$Reins\_Sus\_p50_{i,t}$		$Reins\_Sus\_p75_{i,t}$	
Model	one-step GMM-system							
Variables	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
$UW\_profit_{i,t-1}$	0.06070	0.07582	0.02913	0.07460	0.12267	0.07713	0.09349	0.09333
Control variables	Yes		Yes		Yes		Yes	
N	8,544		8,544		8,544		8,544	
Firms	1,426		1,426		1,426		1,426	
λ^2 value (p value)	504.51 ***(0.000)		554.43 ***(0.000)		702.21 ***(0.000)		960.41 ***(0.000)	

Note: ***, **, * represent statistical significance at 0.01, 0.05, and 0.1 levels, respectively.

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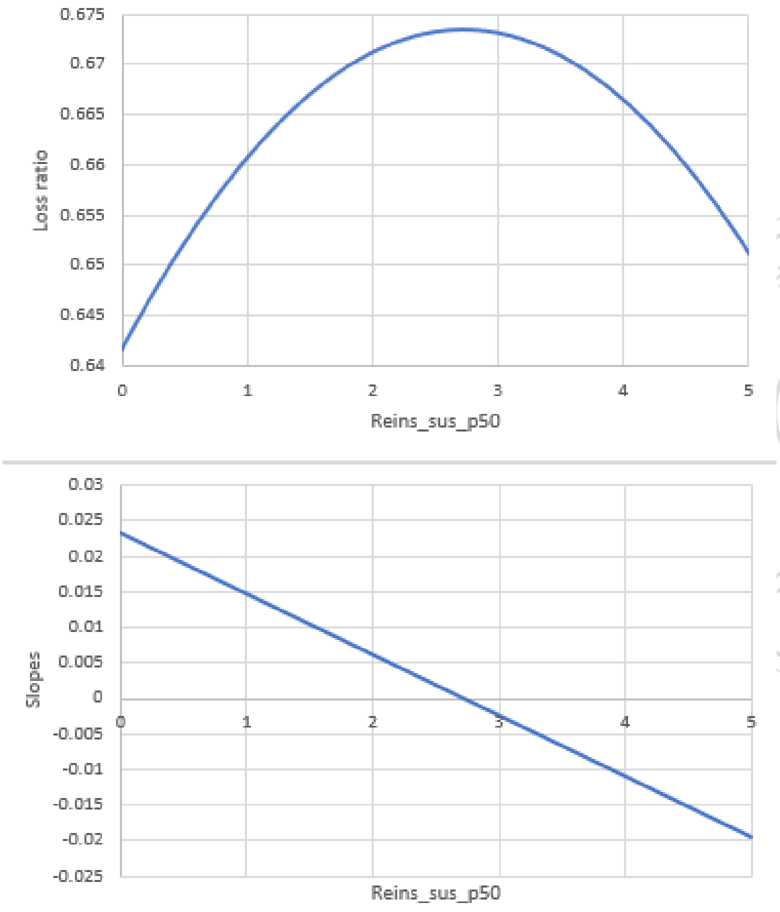
Figure 1: The (inverted) U-shaped relationships between the relation's duration and loss ratio, combined ratio, and underwriting profitability.

Panel A: Loss ratio



Panel B: Combined ratio

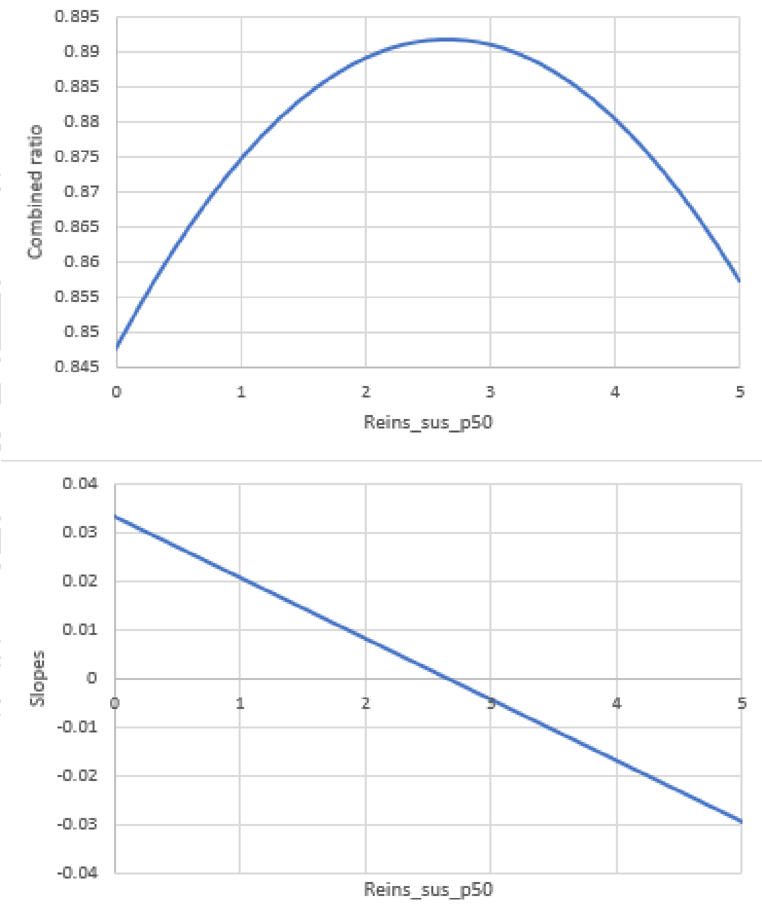


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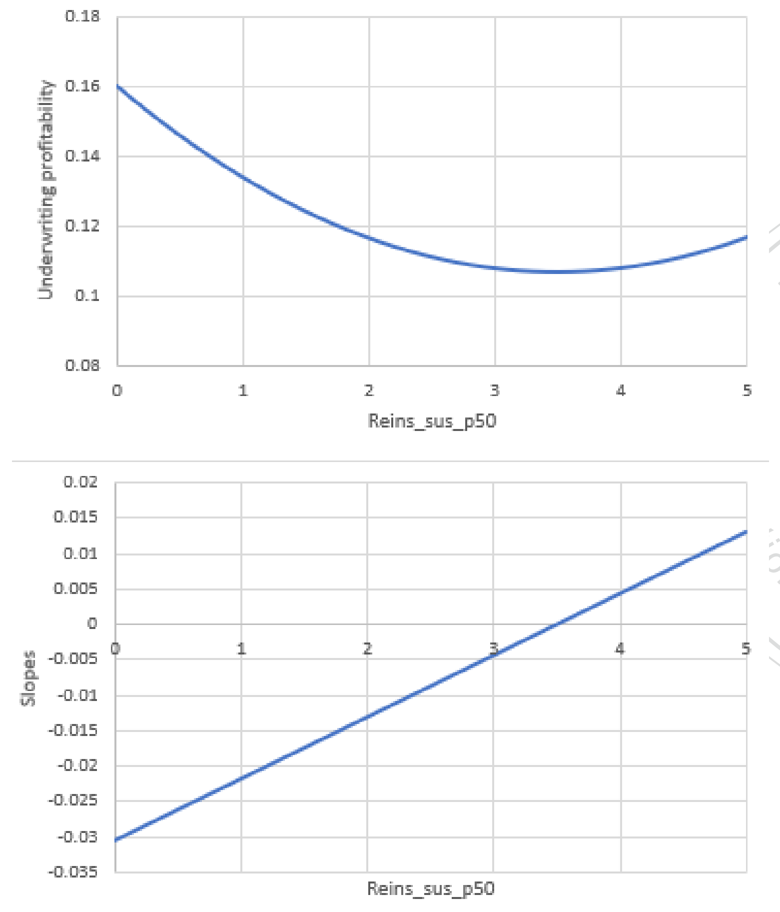
Figure 1: The (inverted) U-shaped relationships between the relation's duration and loss ratio, combined ratio, and underwriting profitability.

Panel C: Underwriting profitability



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Essay 2

The Effects of the Tenure of Insurer-Reinsurer Relationship on Product Diversification: Evidence from the US Property-casualty Insurance Industry

Abstract

Prior studies mainly investigate whether asymmetric learning exists in (re)insurance market. However, no studies investigate how the tenure of insurer-reinsurer relationship, asymmetric learning, in reinsurance market further affects underwriting strategies adopted by insurers. This study investigates the effects of the tenure of insurer-reinsurer relationship on product diversification of US property-casualty insurers by using NAIC database from 2012 to 2020. The results show that the tenure of insurer-reinsurer relationship increases the extent of product diversification, consistent with asymmetric learning hypothesis and real service hypothesis. In addition, the results also show that the tenure of insurer-reinsurer relationship-product diversification relation is moderated by the insurer's size. Robustness test using alternative product diversification measure document consistent results. The implication is that maintaining long-term relationship equip insurers with lower reinsurance premium and real services provided by reinsurers. Therefore, it is beneficial for insurers to maintain long-term relationship with reinsurers.

Keywords: The tenure of insurer-reinsurer relationship, Product diversification, Firm size, Asymmetric learning hypothesis, Real service hypothesis

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1. Introduction

Diversification is regarded as a natural hedging or a risk management strategy for property-casualty insurers. Although diversification provides benefits for insurers to reduce underwriting risk, however, the recent trend documents that the insurers in US property-casualty industry tend to adopt more focused strategies by insurance product lines in recent years (Shim, 2011). Previous studies found that more diversified insurers are prone to experience worse value and performance (Ai et al., 2018). It indicates that diversification may induce more cost than benefit in insurance industry since senior managers of more diversified insurers may discover that it becomes more difficult to coping with more business lines with dissimilar character (Jones and Hill, 1988), incurring a high coordination cost. In addition, diversification is accompanied by agency problems between managers and shareholders (Andreou et al., 2016). Therefore, what factors induce US property-casualty insurers to diversify is a topic of concern for academic researchers, practitioners, and regulators.

Reinsurance is inherently an important type of risk management tool in property-casualty insurance industry (Plantin, 2006) due to its mechanism of transferring risks which are characterized by unpredictable, low-frequency, and high-severity (Froot and O'Connell, 2008). It is a contract written by the reinsurer indemnifying the cedant for random loss events (Doherty and Tinic, 1981). The reasons for purchasing reinsurance include lower insolvency probability, capital requirement, and uncertainties resulting from regulatory changes or catastrophic losses and enhance underwriting capacity and liquidity (Doherty and Lamm-Tennant 2009; Park et al., 2019). Moreover, reinsurance equips cedants to possess smaller and predictable risks and transfer larger but less predictable risks to reinsurers (Altuntas et al., 2018).

However, information asymmetry may exist between reinsurance contracting parties. From the studies of Akerlof (1978) and Rothschild and Stiglitz (1976), many information economic theorists began to concentration their attention to the information asymmetry related issues and further examine whether such phenomenon exists in various types of insurance contracts and (re)insurance markets theoretically and empirically. In information asymmetry literature, studies mainly focus on examining whether information asymmetry exists in certain types of insurance or reinsurance markets (Cohen and Siegelman, 2010; Chen and Shiu, 2020a). Another strand of research focuses on whether asymmetry learning exists in certain insurance market (Shi

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and Zhang, 2016) or reinsurance market, theoretically (Jean-Baptiste and Santomero, 2000) or empirically (Garven et al., 2014). However, only Garven et al. (2014) investigate the issue of asymmetric learning by empirically examining whether reinsurance, return on assets, and credit quality improves as the tenure of insurer-reinsurer relationship increases.[39] None of the studies further explore how such asymmetric learning further affects the underwriting strategies adopted by cedants. Hence, whether the tenure of insurer-reinsurer relationship affects the insurers' underwriting strategies is an important and not yet being explored issue that needs to be addressed to fill the research gap in information asymmetry literature.

It is well known that the efficiency of reinsurance relies on long-term relationship basis due to the mitigation of information asymmetry resulting in adverse selection and moral hazard and informal control of reinsurance contract (Doherty and Smetter, 2005).[40] The mitigation of adverse selection through long-term relationship or repeated contracting may affect the risk reallocation between reinsurers and insurers. In addition, reinsurers may assist and provide specific knowledge and skills for cedants to expand their business to new business lines. From the aspect of managers, they maintain overall risk at a certain level, minimize the costs of risk management, and maximize their profitability. Therefore, this study intends to investigate whether long-term relationship in reinsurance market affects the underwriting strategies, product diversification strategies, adopted by insurers.

However, such effects may be mitigated by insurer's firm-level characteristics, firm size, since, firstly, information asymmetry between a larger insurer and a reinsurer is lower than that between a smaller insurer and a reinsurer and, secondly, larger insurers demand less reinsurance. In addition, larger firms tends to diversify more than smaller firms. Therefore, this study also investigates whether firm size mitigates such effects to give a detailed picture on what factor moderates the effects of the tenure of insurer-

[39] We use the term "the tenure of insurer-reinsurer relationship" since long-term implicit contracts come from repeated reinsurance contracting or non-cancellation of continuous reinsurance contracts (Garven et al., 2014).

[40] The reinsurance contract is less formal relative to the standard insurance contract in insurance industry (Doherty and Smetters, 2005). In terms of reinsurance market, reinsurers obtain the private information about the underwriting information of ceded business, which is written by repeated insurers, that other potential reinsurance sellers do not have. Hence, reinsurers may have ex post market power when asymmetric learning takes effect since the reinsurers include the new private information into reinsurance pricing (Jean-Baptiste and Santomero, 2000). In addition, reinsurers could monitor primary insurers to prevent opportunistic behaviors, provide incentives for primary insurers to underwrite and settle claims more carefully and provide expertise to primary insurers to assist them to underwrite other lines of business at a lower cost (Doherty and Smetters, 2005; Anand, Leverty and Wunder, 2020).

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reinsurer relationship on product diversification.

The motivation of this study is fourfold. First, this study attempts to combine information asymmetry and diversification literature to fill the research gap since prior studies investigate whether information asymmetry (Yan and Hong, 2015) or asymmetric learning (Garven et al., 2014) exists in reinsurance markets empirically. In addition, less studies empirically investigate what factors affects the diversification strategies adopted by insurers. Specifically, none of the studies examine whether long-term relationship in reinsurance market affects underwriting strategies adopted by insurers. Second, the US property-casualty insurance industry is very competitive in terms of price, quantity, the number of insurance firms, insurance products, and services insurers (Shim, 2017; Chang, 2019).[41] In addition, compared to life counterparts, property-casualty insurance industry is generally conservative (Liu, Shiu, and Liu, 2016), short term and subject to a high level of claims payment uncertainty in terms of the size and timing of potential claim costs, especially for the business exposed to catastrophe risk (Eling and Marek, 2014; Shiu, 2016). Moreover, the extent of business line classification in property-casualty industry is greater than that of life and health industry (Che and Liebenberg, 2017). Therefore, we focusing on US property-casualty insurance industry. Third, there might be some differences between larger insurers and smaller insurers. For example, information asymmetry between managers and outsiders is lower for larger insurers than that for smaller insurers since larger firms tends to be more transparent and monitored by various stakeholders. In addition, larger insurers demand less reinsurance and tend to engage in diversifying. Therefore, whether firm size moderates such effects is also an interesting issue. Fourth, diversification is an important corporate decision and the incentives behind its decision and the effects of diversification on performance are concerns and debated by many scholars (Fan et al., 2020). In addition, product line diversification is a key risk management strategic for property-casualty insurance industry and such effects are widely debated (Ai et al., 2018). Over the past decades, many studies focusing on insurance industry focus on investigating the effects of diversification on performance (Morris et al., 2017). However, less insurance studies focus on the determinants of product diversification

[41] Specifically, more than 2,500 insurers compete each other and provide services for millions of customers. In addition, insurance products provided by insurers could be classified into appropriately 40 categories. Insurance product prices and underwriting profitability may decrease since the market competition intensifies (Che, 2019).

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(Berry-Stölzle et al., 2012). Therefore, this study intends to provide empirical evidence to present that long-term relationship in reinsurance market is another factor affecting product diversification of insurers.

This study uses the National Association of Insurance Commissions (NAIC) dataset covering the year from 2012 to 2020 to investigate whether product diversification altered as the tenure of insurer-reinsurer relationship increases and further examines whether firm size moderates such effects. Regarding the empirical models used in this study, we use ordinary least squares (OLS) and random effect Tobit model (RETobit) to capture such relationships.

We document that insurers diversify more with the increase of the tenure of insurer-reinsurer relationship. The results may indicate that insurers acquire the real service provided by reinsurers as the tenure of insurer-reinsurer relationship increases. In addition, they underwriting new business for increasing premium income at a lower cost since they could purchase reinsurance at a lower cost due to lower information asymmetry. Specifically, since reinsurance premium offered by the incumbent reinsurers decreases as the tenure of insurer-reinsurer relationship increases, the repeated contracting insurer could purchase more reinsurance and further increases more underwriting capacity. Thus, maintaining long-term relationship with reinsurers enables cedants underwrite more new businesses to increase decrease risk. In addition, we also find that firm size mitigates the effects of the tenure of insurer-reinsurer relationship on product diversification, suggesting that the effect is more pronounced for smaller insurers.

The study close to our study is Garven et al. (2014). Garven et al. (2014) investigates the effects of the tenure of insurer-reinsurer relationship on the ceding insurers' bankruptcy risk, financial performance, and reinsurance usage. However, this study investigates the tenure of insurer-reinsure relationship on product diversification and investigate whether firm size moderators such effects. In addition, Garven et al. (2014) find that the tenure of insurer-reinsurer relationship increases credit quality, reinsurance usage, and financial performance. Our study finds that the extent of diversification in terms of business mix increases with the tenure of insurer-reinsure relationship. In addition, we also find that firm size mitigates the effects of the tenure of insurer-reinsurer relationship on total line-of-business diversification. In sum, Garven et al. (2014) find that such tenure affects insurers' financial performance. However, this study

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finds that tenure affects underwriting strategies adopted by insurers.

The contribution of this study is fourfold. This is the first study to investigate how long-term relationship between insurers and reinsurers in reinsurance market affects the underwriting strategies adopted by insurers. In addition, this study contributes to the information asymmetry and diversification literature to provide another aspect of how long-term relationship in reinsurance market affects the insurers' underwriting strategies. In addition, this study also finds that researches in the future should take firm size into consideration when investigating the effects of the tenure of insurer-reinsurer relationship. Second, the empirical results of this study further extend the results of Garven et al. (2014). Specifically, this study extends the empirical literature by providing empirical evidence supporting the notion that how long-term relationship in reinsurance market mitigates adverse selection and further affects underwriting strategies adopted by insurers. Third, this study provides additional insights for regulators. For regulators, they could adopt policies providing incentives for insurers to maintain long-term relationship with the same reinsurers since they could further take diversify business to activate the insurance market, especially for smaller insurers. Finally, this study improves the reinsurance sustainability measures by considering the importance of reinsurance transaction. Specifically, we first calculated the accumulated reinsurance premium in the past 5 years and then choose the observations to be included in this study based on such amount. Next, we construct four measures of reinsurance sustainability based on the observation chosen.

This essay proceeds as follows. Section 2 review the information asymmetry and diversification literature step by step and further derive two testable hypotheses. Next, we describe the data, variable developments and regression settings in the subsequent section. Then, we present the empirical results and discusses the reasons in the fourth section, including the reverse causality testing. Moreover, we conduct robust checks in the fifth section to see whether the results may be impacted by the number of business lines. Finally, the last section offers the concluding remarks and future research.

2. Literature Review and Hypothesis Development

In this section, I review both information asymmetry and diversification literature to lead readers to know the recent research boundary and the research gap in the literature. Next, I derive two testable hypotheses regarding how product diversification is

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influenced with the increase of the insurer-reinsurer relationship and how firm size mitigates such effects.

2.1 Literature Review

In this section, we introduce the literature on information asymmetry, asymmetric learning and diversification, respectively. To describe how this strand of research develop and what are the research trends and research boundaries. Finally, we discover the gap in the literature.

2.1.1 Information asymmetry

Studies focusing on information asymmetry starts from Akerlof (1978) and Rothschild and Stiglitz (1976). The following insurance empirical studies further examine whether information asymmetry exists in certain insurance markets or insurance pools in certain segments of an insurance market.[42] However, the empirical results in prior studies do not present consistent phenomena and the existence of information asymmetry varies with various insurance markets or insurance pools (Cohen and Siegelman, 2010).

Recently, few studies begin to explore the issues of information asymmetry in reinsurance markets. The first theoretical research began from Jean-Baptiste and Santomero (2000), providing a theoretical analysis deriving three hypotheses on how the efficiency of the risk allocation improves as the tenure of insurer-reinsurer relationship lengthens. Their theory asserts that the insurers utilize high level of reinsurance at a more favorable price, have better financial performance and credit quality since adverse selection between them is mitigated with the increase of the tenure of insurer-reinsurer relationship.

Empirical published studies concentrating on information asymmetry in reinsurance markets start from Yan (2013). Yan examines whether the phenomenon of residual moral hazard exists in US property-casualty reinsurance industry. Specifically, the way that conducted is by examining whether moral hazard in external reinsurance is more severe than that in internal reinsurance. The results suggest that the overall US

[42] For instance, prior studies examining whether information asymmetry exists in private accident insurance market (Spindler, 2015), private long-term care insurance market (Browne and Zhou-Richter, 2014), automobile insurance market (Gao, Powers and Wang, 2017), life insurance market (He, 2009), private health insurance (Olivella and Vera-Hernández, 2013), crop insurance (He et al., 2018), annuity market (Finkelstein and Poterba, 2004) and cancer insurance market (Wang et al., 2011).

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reinsurance markets are efficient. Yan and Hong (2015) investigate information asymmetry issues in three major US reinsurance markets and find the existence of information asymmetry in the product liability reinsurance market but do not find such phenomena exist in the private passenger auto liability and homeowners reinsurance markets. Chen and Shiu (2020a) explore whether information asymmetry exists in Taiwan non-life reinsurance industry and find that such phenomenon exists. Additionally, they find that information asymmetry is more severe for insurers with higher loss ratio. Chen and Shiu (2020b) also examine the existence of information asymmetry in Taiwanese non-life fire reinsurance market and show that such phenomenon does not exist. Therefore, based on previous literature reviews, we do not have prior expectations on whether information asymmetry exists in certain reinsurance market.

2.1.2 Asymmetric learning

Another strand of research focuses on the issues of asymmetry learning in (re)insurance markets. Asymmetric learning phenomenon denotes that adverse selection is not static since both reinsurers and cedants may learn about the risk type of policyholders in the context of reinsurance market. Vast studies have developed multiperiod models of asymmetric learning in various markets. For example, in credit market context, asymmetry learning denotes that incumbent banks acquire more information of the repeat borrowers over time than other rival banks have and thus have market power on borrowers since the quality of borrowers is gradually known to incumbent banks by learning over time but is not known to the rival banks (see Sharpe, 1990).

In insurance market context, theoretically, Kunreuther and Pauly (1985) and de Garidel-Thoron (2005) derive models presenting that insurers learn information concerning policyholders contracting repeatedly and have competitiveness advantage over other rival insurers. Empirically, many insurance studies examine various insurance market and acquire various conclusions. Some studies find that asymmetric learning exists, indicating that insurers gradually learn about the risk type of repeat policyholders, in Israel automobile market (Cohen, 2012), Australian auto insurance industry (Kofman and Nini, 2013), and automobile insurance market in Singapore (Shi and Zhang, 2016). However, asymmetric learning does not exist in group insurance in China (Eling et al., 2017).

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Second, another round of research scrutinizes whether asymmetric learning exists in reinsurance market. Jean-Baptiste and Santomero (2000) is the first theoretical research scrutinizes asymmetric learning related issues by deriving three hypotheses. Next, Garven et al. (2014) empirically explore whether asymmetric learning exists by empirically providing evidences supporting the hypotheses of Jean-Baptiste and Santomero (2000). Specifically, by using the panel data of US property-liability industry covering the year from 1993-2012, they find that insurers purchase more reinsurance, have lower bankruptcy risk and have better financial performance, indicating that asymmetric learning exists in US property-casualty industry.

2.1.3 Product Diversification

Since the seminal work of Rumelt (1974), finance and insurance literatures began to explore the issues of diversification into two strands. The first trend investigates the reasons of why firms engage in various types of diversification and its implications. On one hand, the benefits of diversification may include risk reduction [43], scope economies [44], larger internal capital markets, and a greater capacity to grow new business (Upreti and Adams, 2015). On the other hand, certain studies taking on opposite view contend that firms perform better by adopting focusing strategy rather than other insurers adopting diversification strategy, consistent with the view of strategic focus hypothesis or quiet life hypothesis.[45] The benefits of focusing suggest the costs associated to diversification strategy since such strategy not only aggravates agency costs but also gives rise to cross-subsidization problem within poorly performing businesses (Bolton and Scharfstein, 1990; Fresard, 2010). Therefore, prior theories provide competing arguments and evidences connected with the impacts of product diversification on insurer's various performance (Berry-Stölzle et al, 2013). The other round of research scrutinizes how diversification affects performance. Among these studies, one strand of research examines whether diversification discount exists (Servaes, 1996). Another strand of research takes endogeneity into account,

[43] Portfolio theory argues that firms diversifying more have lower earnings volatility benefit through "coinsurance effect" (Boot and Schmeits, 2000).

[44] The benefits resulting from economies of scope in insurance market include many aspects. For example, it enables insurers to have the ability to enhance brand image, cross-sell products, generate cost savings and grow new markets (Best's Review, 2000).

[45] The quiet life hypothesis denotes that firms face lower competitive pressure since they have substantial market power and thus the managers of the firms can purely focus on the lines that have expertise in and do not have to worry too much about losing customers (Hicks, 1935; Rhoades and Rutz, 1982).

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suggesting that, prior to diversification events, firms diversifying have previously been traded not at a fair value but at a discount (Lang and Stulz, 1994). The other round of research argues that measurement error is the main reason for the existence of diversification discount evidenced by prior studies since they found evidences presenting that firms traded at a premium tend to diversify instead of those traded at a discount (Villalonga, 2004). Therefore, prior diversification studies do not reach a consistent conclusion on how diversification affects firm performance in the finance literature.

The diversification literature on insurers mainly investigates the effects of product diversification or related diversification on performance but less studies scrutinize the determinants of insurer's diversification. Generally, since the cost of diversification often outweigh the benefits of diversification in insurance industry, the net effect is negative and diversification discount exists (Hoyt and Trieschmann, 1991; Berger et al., 2000; Liebenberg and Sommer, 2008; Eling and Luhnen, 2010; Berry-Stölzle, Hoyt, and Wende, 2013; Morris et al., 2017; Ai et al., 2018, Savitha, Banerjee and Shetty, 2019).[46] In addition, the other empirical studies find that business diversification is complex non-linearly correlated with performance (Elango et al., 2008; Ai et al., 2018).

Regarding the empirical studies focusing on product diversification issues in US property-casualty industry, Berry-Stölzle et al. (2012) investigate what factors have an influence on the corporate diversification strategies on US property-casualty insurers. Their results denoting that insurers do not tend to diversify when they have underwritten more high-risk business lines. The empirical results of Liebenberg and Sommer (2008) document that non-diversified P/L insurers on average outperform those diversifying, consistent with strategic focus hypothesis. Berry-Stölzle et al. (2013) scrutinize whether the impacts of product diversification on financial performance differ across countries.

[46] Cummins, Weiss, and Zi (2003) make use of the sample of property-casualty insurance industry in US covering the period from 1993 to 1997 and a type of efficiency analysis, data envelopment analysis. The results document evidences weakly supporting economies of scope hypothesis. Therefore, they contend that it is more efficient for insurers to adopt strategic focus strategy than to adopt conglomeration strategy. Cummins et al. (2010) document that value and competencies are added by insurers focusing on core businesses. Eling and Luhnen (2010) contend that it is less efficient for insurers to adopt diversification strategy than to adopt focus strategy in property-casualty insurance industry. Morris et al (2017) investigate the related diversification and performance. Their results document supporting the notion that the nexus between related diversification and accounting performance exhibits negative, providing evidence showing diversification discount. Savitha, Banerjee and Shetty (2019) focus on the insurance pool of the life microinsurance (LMI) portfolio and further investigate whether both technical efficiency and productivity are impacted by investigating such effects of insurance companies in India. Their evidences present that the strategy of product diversification has lowered technical efficiency of insurers, supporting the strategic focus hypothesis.

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Specifically, they find that less diversified insurers outperform highly diversified counterparties in countries not only with better property rights protection and fierce competition but also with well-developed capital markets. Che and Liebenberg (2017) scrutinize coordinated risk management theory via testing the relationship between product diversification and asset risk-taking. Their results document that diversified insurers undertake higher level asset risk than do non-diversified insurers.

Thus, based on the literature review concerning information asymmetry and diversification, this study intends to bridge the gap via scrutinizing the effects of tenure of insurer-reinsurer relationship on product diversification in US property-casualty industry.

2.2 Hypothesis

In this section, we derive two testable hypotheses regarding the nexus between the tenure of insurer-reinsurer relationship and product diversification. First, we drive and then propose the first hypothesis regarding how business diversification varied with the increase of the tenure of insurer-reinsurer relationship. Second, we derive the second hypothesis indicating how firm size mitigates such effect.

US property-casualty insurance market has a feature of completely competitive market (Chang, 2019). Insures intending to grow new business must have comparatively advantage over rival insurers in the market. However, reinsurance purchasing enables insurers have advantages over rivals (Upreti and Adams, 2015). In addition, information asymmetry exists between insurers and reinsurers when reinsurance contracting (Jean-Baptiste and Santomero, 2000). Specifically, first, reinsurers do not underwrite the business directly since reinsurance is the second layer of insurance (Jean-Baptise and Santomero, 2000). Second, the reinsurance contracts are informal and not as standard as insurance contracts (Doherty and Smetters, 2005). Third, such phenomenon could be reinforced through reinsurance brokers. Specifically, reinsurance brokers provide advice quality and charge price for cedants but advice quality and price are lower and higher than social optimal level (Sonnenholzner, Friese,

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and Schulenburg, 2009).[47,48] Additionally, poor advice quality occurs within the reinsurance transaction and reinsurance brokers have incentives to pretend high-risk business as low-risk business for better reinsurance terms and price to acquire higher reinsurance commissions from reinsurers.[49] Fourth, managers have incentives to hide the real underwriting information regarding the riskiness of the high-risk ceded business and pretend them as low-risk, indicating that insurers have superior information, regarding the riskiness of ceded business, that reinsurers lack. Additionally, information asymmetry results in adverse selection and moral hazard (Cohen and Siegelman, 2010). Specifically, adverse selection, in terms of the ceded business in reinsurance market, indicates that high risk business is prone to be ceded since the reinsurers do not have underwriting information regarding the riskiness of the ceded business to distinguish between high-risk and low-risk ceded businesses. Moral hazard denotes that the insurers are less likely to invest in precaution measures and put efforts that reduce the probability or the size of the loss of the ceded business since purchasing reinsurance reduces the benefits from the efforts put by primary insurers into loss prevention and mitigation (Cohen and Siegelman, 2010).

Maintaining long-term relationship in reinsurance market is a common practice for practitioners (Doherty and Smetters, 2005). Specifically, for reinsurers, long-term relationship mitigates information asymmetry.[50] In addition, adverse selection and moral hazard are further mitigated with the longer reinsurance relationship. Moreover, asymmetric learning exists in US property-casualty reinsurance market (Garven et al., 2014). Specifically, during the reinsurance contract effective period, underwriting information concerning the riskiness of ceded business is gradually revealed in the forms of incurred claims. The current reinsurers acquire such private information over time and include such information into risk classification, monitoring, and reinsurance

[47] In reinsurance broker markets, advice quality means the level of reinsurance brokers' realization regarding mismatches of cedants to promote the reinsurance selling probability (Gravelle, 1994). In addition, price mentioned in reinsurance broker markets implies the markup specified by a broker rather than the total reinsurance price charged by a reinsurance broker (Sonnenholzner et al., 2009).

[48] Reinsurance brokers are reluctant to put their efforts into promoting their advice quality since the cost structure is not linear but both increasing and convex (Sonnenholzner et al., 2009).

[49] Reinsurance brokers have incentives to engage in opportunistic behaviors to acquire more commissions by selling the reinsurance policies with higher reinsurance commissions (Marvel, 1982; Gravelle, 1994). Thus, poor advice quality may occur since reinsurance brokers are prone to be dishonest and attract cedants to purchase unnecessary reinsurance.

[50] In this study, we follow Jean-Baptiste and Santomero (2000) and assume that the importance of contingent pricing schemes (loss-sensitive contracts and deductibles design) decreases as the length of the tenure of insurer-reinsurer relationship increases.

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pricing (Jean-Baptiste and Santomero, 2000; Doherty and Smetters, 2005).[51] [52] Specifically, reinsurance premium is related to the tenure of insurer-reinsurer relationship since long-term relationship improves the information flow and thus mitigate adverse selection cost (Jean-Baptiste and Santomero, 2000; Garven et al., 2014). Specifically, reinsurers charge high-risk cedants with higher reinsurance premium or stop renewing but with lower reinsurance premium for low-risk cedants. For ceding insurers, they tend to purchase reinsurance with the reinsurers providing lower reinsurance premium. Thus, low-risk cedants tend to retain with the current reinsurers since the current reinsurers know more about the quality of the business but other reinsurers have no information regarding such quality. However, high-risk cedants tend to switch their business to other reinsurers to fleet their records for lower reinsurance premium. Therefore, cedant retaining with the current reinsurance relationship tends to be low-risk cedants. In addition, adverse selection decreases with the increase of the tenure of insurer-reinsurer relationship.

In addition, insurers also monitored by reinsurers. Specifically, monitoring the underwriting activities of the insurers and how the insurers settle claims incurs much cost. In addition, the extent of monitoring increases with the level of reinsurance relationship (Doherty and Smetters, 2005). Thus, insurers become more conservative and prudent in underwriting. With more private information, the cost of monitoring lowers and reinsurers could lower reinsurance premium due to the savings of reduced monitoring cost as the reinsurance relationship intensifies (Bharath et al., 2011). Thus, moral hazard also reduced as the tenure of insurer-reinsurer relationship lengthens. Therefore, adverse selection and moral hazard are mitigated as the tenure of insurer-reinsurer relationship increases.[53]

Reinsurance premium charged by current reinsurers reduces as the tenure of reinsurance relationship increases due to lower adverse selection and moral hazard.

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[51] Risk classification in reinsurance market denotes that the reinsurers use observable information to price or structure reinsurance policies. It also assists reinsurers to group ceded risk with similar expected cost. Therefore, it enables reinsures to calculate the reinsurance premium and reduce adverse selection (Dionne and Rothschild, 2014).

[52] Specifically, reinsurers would reevaluate the risk type of the ceded business with new observable information and further offer high reinsurance price for insurers when the loss experience of ceded business worsens (Chiang, 2020).

[53] In the first essay, we have found that information asymmetry increases when the relation’s duration is short but decreases when such duration is long. Overall, the trend of the effects of such duration is consistent with the concept indicating that, on average, asymmetric information decreases with the increase of such duration of reinsurance relationship.

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Thus, based on renting capital hypothesis, insurers could have high level of underwriting capacity by purchasing high level of reinsurance since their the cost of risk management (contingent capital) decreases with the increase of the reinsurance relationship. In addition, with more private information, reinsurers become familiar with the cedants. Since the main reason for insurers to purchase reinsurance is to have access to the real service, reinsurers could further provide expertise and specialized knowledge that the insurers lack, encouraging insurers to expand their business to other business lines, based on real service hypothesis (Anand et al., 2020).[54]

Insurer managers have incentives to adopt diversification decisions. Specifically, they expand business by underwriting new line business to increase their private benefits (Jensen, 1976), or preserve their human capital (Amihud and Lev, 1981) since maintaining higher capital buffer than appropriate level opportunity cost rises when the level of capital buffer is larger than the appropriate level (Chen, Chang, and Shiu, 2021) and the insurers may face growth constraints in the current insurance products they operate in (King and Tucci, 2002). In addition, business diversification is linked with various benefits, including cost scope economies, better access to internal capital market, and avoid unfavorable underwriting cycle (Ai et al., 2018).[55,56] Therefore, based on the previous discussions, insurers renewed by current reinsurers tend to diversify more.

Insurers not being renewed by current reinsurers may have poor loss experience. Poor underwriting performance may result from high coordinating costs. Although they transfer most of the underwriting risk to reinsurers, their insolvency risk is high due to the specification of coinsurance rate or retention level for proportional or non-proportional reinsurance structure or both (Boyer and Dupont-courtage, 2015) when huge loss occurs. Based on strategic focus hypothesis, they tend to focus on the business lines they have core competencies in for specialization (Peng and Lian, 2020), better risk pricing (Mankai and Belgacem, 2016), lower monitoring cost (Mayers and Smith, 1988), pursuit high efficiency (Cummins, Weiss, and Zi, 2003), and promote performance (Berry-Stölzle et al., 2013) to improve their loss experience since they are

[54] For the business lines that cedants already have experts in, they tend to retain the business with the current reinsurers for lower reinsurance premium and for higher underwriting capacity.

[55] Cost scope economies denotes that insurers could share product inputs when products insurance products jointly (Teece, 1980).

[56] Insurers operating in certain lines of business might experience severe badly loss experience in case that all business lines are facing unfavorable underwriting cycle simultaneously. (Shiu, 2016).

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subject to high monitoring from regulators. [57,58] In addition, they tend to retain the old low-risk customers for better loss experience (Pooser and Browne, 2018). Therefore, insurers not renewed by current reinsurers tend to adopt focusing underwriting strategy.

Therefore, based on the previous discussions and on the asymmetric learning hypothesis and real service hypothesis, we propose the first hypothesis:

Hypothesis 1: The extent of product diversification increases as the tenure of insurer-reinsurer relationship increases.

However, the effects of insurer-reinsurer relationship on product diversification are not homogenous for all insurers. Such effects may be mitigated with the increase of insurers' size since information asymmetry between reinsurers and insurers decreases with the increase of insurers' size and larger insurers demand less reinsurance and real services provided by reinsurers.

First, information asymmetry between larger insurers and reinsurers is lower than that between smaller insurers and reinsurers. Specifically, information asymmetry between firm's insider and outsider is lower for larger insurers than for smaller insurers (Smith, 1977) since larger insurers are prone to be monitored by various stakeholders, for example, stockholders, policyholders, analysts, independent directors and regulators, indicating that larger insurers have less private information in the reinsurance relationship than do the smaller insurers.[59] Managers of larger insurers tend to be treated with high salaries, more compensations and have higher reputation than those managers of smaller insurers. Thus, they are less likely to engaging in opportunistic behaviors by hiding the real information regarding the riskiness of the ceded business to the current reinsurers since their opportunity cost of losing their job is higher than those of smaller insurers.

Second, larger insurers are in less need for reinsurance (Hoerger, Sloan, and Hassan, 1990; Powell and Sommer, 2007). Based on bankruptcy cost hypothesis, larger insurers have lower default probability than smaller insurers since the average losses may be

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[57] Managerial discretion hypothesis, proposed by Mayers and Smith (1988), denotes that, for owners, high returns and low monitoring costs could be achieved when insurers focus and operate in fewer business lines.

[58] Although diversification lowers underwriting risk by smoothing expected cash flows, highly diversified insurers perform worse than those focusing on core business lines.

[59] In terms of reinsurance relationship, reinsurers are considered as outsiders from the angle of insurers.

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more predictable for an insurer underwriting a larger pool of policyholders, (Jensen and Meckling, 1976; De Haan and Kakes, 2010). In addition, larger insurers have high risk tolerance, more resources and underwriting capacity, have access to finance the low-cost funds in the short run to cover large losses (Shiu, 2016), and undertake greater or complicated risk (Titman and Wessels, 1988; Xie et al., 2020) without reinsurance. Furthermore, larger insurers tend to be highly diversified since they attract more talents, accumulate more underwriting techniques and devote more resources in risk management. Therefore, less reinsurance is used for larger insurers than smaller insurers.

Since adverse selection between cedants and reinsurers is lower for large insurers than for smaller insurers and reinsurance demand is lower for larger insurers, the effect of asymmetry learning phenomena lowers with the increase of insurer's size. Specifically, in terms of underwriting capacity and reinsurance premium, the increase of underwriting capacity on average is smaller for larger insurers than for smaller insurers and the reduction of reinsurance premium on average is lower for larger insurers than for small insurers as the reinsurance relationship lengthens since adverse selection is lower for larger insurers than for small insurers. In sum, smaller insurers tend to diversify more than larger insurers since the benefit of asymmetric learning resulting from retaining reinsurance relationship is higher for smaller insurers than larger insurers. Moreover, small insurers tend to grow their new business by more diversifying since they could have access to lower cost of contingent capital. In addition, relative to larger counterparts, smaller insurers finance at a higher cost in the capital markets. Therefore, we thus propose the second hypothesis as follows:

Hypothesis 2: The effect of an increase of product diversification when the tenure of insurer-reinsurer relationship lengthens is mitigated with the increase of the insurer's size.

3. Data, Variables, and Methodology

Since the tenure of insurer-reinsurer relationship is likely to affect product diversification and firm size is also likely to mitigate such effects. Hence, in this section, we precisely describe the data, variable developments and regression models used in this study step by step.

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3.1 Sample selection

Initially, our sample for analysis contains all insurers recorded in the NAIC Infopro database for the period from 2012 to 2020.[60] The number of property-casualty insurers in 2012 and 2020 are 3028 to 2853, respectively. An unbalanced panel data is used. We then remove insurers reporting negative direct premiums written, surplus, and total admitted assets, missing values and other values considered to be illogical and unreasonable by prior studies (Chang, 2019). We then exclude the insurer that is regarded as a reinsurer by screening whether the ratio of assumed business to gross business is over 0.75 (Cole and McCullough, 2006). Following Berry-Stölzle et al. (2012), we include the insurers with only stock or mutual form and remove other type of insurers. Next, we eliminate observations if the ratio of reinsurance ceded (internal plus external) to the sum of direct premiums written and reinsurance assumed is above one or below zero (Shiu, 2011). We also exclude insurers that are not domiciled within the United States (Hsu, Huang and Lai, 2015). In addition, we exclude firms that operate less than 5 years since we could not create 5-year reinsurance sustainability data.

Finally, our sample contains 13,323 firm-year observations from the year 2012 to 2020. Moreover, 2,081 insurers are included in this analysis. The information concerning the reinsurance counterpart and reinsurance transaction with each counterpart for each insurer is acquired from the NAIC Schedule F–Part 3. Specifically, we collect the information of reinsurer's names and the amount of reinsurance premium ceded to calculate reinsurance sustainability in the next section.

3.2 Variables

This section introduces the variables used in this study. Table 1 presents the abbreviations, definitions, and the corresponding expected effects. We follow Berry-Stölzle et al. (2012) and Ai et al. (2018) to construct our dependent variables, product diversification. The main independent variable, sustainability index, is mainly referred from Garven et al. (2014). The other control variables are referred to Berry-Stölzle et al. (2012). Next, we describe the meanings and definitions of the variables and further

[60] The time periods of dependent variable, product diversification, ranges from 2012 to 2020. We include 1-year lagged product diversification as independent variables for alleviating omitting variable problems. Regarding the independent variables, except for the reinsurance sustainability variable, the time periods of independent variables ranges from 2011 to 2019 due to the 1-year lagged variable specifications. Moreover, the time periods of reinsurance sustainability ranges from 2007 to 2019.

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explain how independent variables influence the dependent variable, respectively. Finally, we made prediction of how independent variables influence dependent variables.

<Table 1 is inserted here>

3.1.1 Dependent variable

Product Diversification

Standard approach for constructing the measure of insurer's product diversification is used in this study. Specifically, such measure is built on the foundation of a Herfindahl concentration index composing of net premiums written across various business lines (Mayers and Smith, 1994; Baranoff and Sager, 2003; Berry-Stölzle et al., 2012; Ai et al., 2018). As mentioned in prior studies, the definition of Herfindahl index HHI_{kt} for insurer k in year t is as follows:

$$HHI_{kt} = \sum_{j=1}^{24} \left(\frac{NPW_{k,j,t}}{NPW_{k,t}}\right)^2 \quad (1)$$

Where NPW_{kjt} indicates net premiums written in business line j＝1, …, 24 as categorized by and reported to the NAIC.[61]

Next, we create the product diversification measure by 1 minus the Herfindahl concentration index.

$$DIV_{kt} = 1 - HHI_{kt} \quad (2)$$

3.2 Main independent variables

Reinsurance sustainability

We follow Garven et al. (2014) and use "reinsurance sustainability" as our measure of the tenure of insurer-reinsurer relationship. To create this sustainability measure, we employ the following steps. First, create 9 separate 5-year rolling windows: 2007-2011, 2008-2012, 2009-2013, 2010-2014, 2011-2015, 2012-2016, 2013-2017, 2014-2018, and 2015-2019, respectively. Second, the effective years within every 5-year rolling window, denoting that a cedant cedes business to each of its reinsurers, are calculated. Specifically, we calculate not only the mean and but also standard deviation values by

[61] We collect the data of net premium written by business lines from Part 1B-Premiums Written (the Underwriting and Investment Exihibit) of the NAIC annual statements. The included business lines are Accident and Health, Aircraft, Auto, Boiler and Machinery, Burglary and Theft, Commercial Multi Peril, Credit, Earthquake, Farmowners', Financial Guaranty, Fidelity, Fire and Allied lines, Homeowners, Inland Marine, International, Medical Malpractice, Mortgage Guaranty, Ocean Marine, Other, Other Liability, Products Liability, Reinsurance, Surety, and Workers' Compensation.

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using each cedant's reinsurance relationship count distribution. The reinsurance sustainability ($Reins\_Sus$) is constructed in equation (1).

$$Reins\_Sus = \frac{\text{mean of the reinsurance relationship count distribution}}{(\text{standard deviation of the reinsurance relationship count distribution}+1)} \quad (1)$$

Within the range of reasonable values, the highest and lowest value for the numerator and denominator are 5 and 1, respectively. The former denotes that a cedant cedes business to the same reinsurers over the specified 5-year rolling window, and the latter suggests that a cedant purchases reinsurance from the same group of reinsurers only lasting 1 year and possibly switches the ceded business to other group of reinsurers. Conceptually, it is considered that persistency denotes the average value of the reinsurer relationship count distribution and consistency is the standard deviation of the reinsurer relationship count distribution. The higher (lower) the average value, the higher (lower) the persistency of the reinsurance relationship with a given reinsurer. Moreover, the higher (lower) the standard deviation, the lower (higher) the consistency of the reinsurance relationship with a given reinsurer. In sum, a cedant receiving high value of reinsurance sustainability maintains long-term reinsurance relationship with the same group of reinsurers, indicating that they have not only high persistency but also high consistency. On contrary, a cedants receiving low value of reinsurance sustainability tend to switch their business to other reinsurance counterparties frequently, denoting that they have low value of persistency and consistency. Specifically, reinsurance sustainability represents a proxy for private information about the riskiness of ceded business that reinsurers lack but used by cedants in reinsurance purchasing decisions. Cedants having low (high) value of reinsurance sustainability have superior (less) information advantage over current reinsurers.

However, the Garven's reinsurance sustainability measure may be distorted by reinsurance transactions with low amount of transaction value due to the inclusions of all reinsurance relationships. Specifically, the reinsurance sustainability measure gives all reinsurance transactions equal weighting when calculating the denominator and numerator. Thus, reinsurance transactions with low amount of reinsurance transaction may bias the value of reinsurance sustainability. Therefore, we follow these concepts of Kysucky and Norden (2016) and Donker, Ng, and Shao (2020) and take the amount of reinsurance premium ceded of the past 5 year's reinsurance transactions into account in generating different reinsurance sustainability measures. In the first stage, we calculate the amount of reinsurance premium ceded over the past 5 years to form the basis of

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importance of reinsurance relationships. For example, the given reinsurance relationship represents the relationship between a cedant i and a given reinsurer j within the specified 5-year rolling window. Next, to capture importance, we consider reinsurance transaction with large amount of reinsurance premium as the important reinsurance relationships. We expect to design 4 scenarios for choosing the observations based on the amount of reinsurance premium ceded over the past 5 years. Then, we generate four reinsurance sustainability variables to emphasize various levels of important reinsurance transaction. In addition, such specification enables us to investigate whether "too-big-to-fail" effect for moral hazard exists if the reinsurance relationship becomes strong.[62]

Next, the reinsurance relation is sorted based on the amount of reinsurance premium ceded over the past 5 years. The first analysis includes all reinsurance transactions as Garven et al. (2014) did. We define the variable name as $Reins\_Sus\_total$. The second analysis excludes the relationship observations whose values are lower than the value of the 25th percentile of all reinsurance relationships and include the other reinsurance relationship observations. Then, we construct the $Reins\_Sus\_p25$ variable. The third analysis excludes the relationship observations whose values are lower than the value of the 50th percentile of all reinsurance relationships and include the other reinsurance relationship observations. Next, we construct the $Reins\_Sus\_p50$ variable. The fourth analysis excludes the observations whose accumulated reinsurance premium lower than the 75th percentile of the accumulated reinsurance premium of overall reinsurance transactions. We construct the $Reins\_Sus\_p75$ variable. In sum, we construct 4 reinsurance sustainability variables, including $Reins\_Sus\_total$, $Reins\_Sus\_p25$, $Reins\_Sus\_p50$, and $Reins\_Sus\_p75$.

Based on hypothesis 1, we expect that reinsurance sustainability, $Reins\_Sus\_total$, $Reins\_Sus\_p25$, $Reins\_Sus\_p50$, and $Reins\_Sus\_p75$, are positively associated with product diversification.

Interaction term

It is defined as the value of firm size multiplied by the value of reinsurance sustainability.

[62] Regarding relationship banking literature, Kysucky and Norden (2016) indicate that a borrower with huge amount of borrowing with banks tend to have incentives to engage in activities resulting in moral hazard in various levels of bank relationships. Specifically, instead of improving their financial condition, the borrower tends to make a gamble by getting more funds from banks.

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This interaction term capture how firm size mitigates the effects of the tenure of insurer-reinsurer relationship on product diversification. Since we construct four reinsurance sustainability variables, we generate four interaction terms, $Interaction\_T_{i,t-1}$, $Interaction\_p25_{i,t-1}$, $Interaction\_p50_{i,t-1}$, and $Interaction\_p75_{i,t-1}$. Based on hypothesis 2, we expect that the interaction term is negatively associated with product diversification.

3.3 Control variables

1-year lagged Product Diversification

To mitigate the omitted variable bias, we include 1-year lagged dependent variable ($P\_Div_{i,t-1}$) as our independent variable (Wooldridge, 2016). We expect that highly diversified insurers tend to continue to diversify more. Thus, we expect 1-year lagged product diversification is positively related to product diversification at time t.

Firm Size

Firm size ($Firm\_size_{i,t-1}$) is calculated as the natural logarithm of total net admitted assets (Che and Liebenberg, 2017).[63] Larger insurers prone to use their brand, reputation and stock of cash resources to enter new markets and sell new products (MacKay and Phillips, 2005; Adam, Dasgupta, and Titman, 2007; Frank and Goyal, 2009; Campello et al., 2011; Berger and Bouwman, 2013; Upreti and Adams, 2015). Empirically, Berry-Stölzle et al. (2012) find that firm size increases product diversification in US property-casualty industry. Hence, we expect firm size is positively associated with product diversification.

Reinsurance

Reinsurance ($Reins_{i,t-1}$) is defined as the ratio of reinsurance premium ceded divided by the sum of direct premium written and reinsurance assumed (Shiu, 2011).[64] Based on renting capital hypothesis, the insurers purchasing more level of reinsurance have more underwriting capacity to operating in new business lines (Shiu, 2011; Upreti and Adam, 2015; Caporale et al., 2017). In addition, based on real service hypothesis,

[63] Since the distribution of total assets of insurers is highly skewed, company size is measured by the means of logarithm in most studies on insurance industry (Pottier and Sommer, 1997).

[64] Specifically, reinsurance ceded includes affiliated reinsurance ceded and non-affiliated reinsurance ceded. Additionally, premium written includes direct business written and reinsurance assumed.

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reinsurers provide expertise and specialized knowledge for insurers.[65] Hence, insurers have incentive to diversify. Empirically, Berry-Stölzle et al. (2012) find that reinsurance induces insurers to have incentives to diversify in product lines. Therefore, we expect that reinsurance is positively and significantly correlated with product diversification.

Stock investment

Stock investment ($Stock\_inv_{i,t-1}$) is defined as the ratio of common stock divided by total invested assets. It is considered as a proxy for insurer's opaqueness (Berry-Stölzle et al., 2012). Based on internal capital market hypothesis, opaque insurers with higher level of opaqueness tend to build an internal capital market, without considering information asymmetry between insiders and outsiders, to mitigate the impacts regarding external financing constrain. Therefore, we expect to find that stock investment is positively correlated with product diversification.

Geographical diversification

Geographical diversification ($G\_Div_{i,t-1}$) is defined as 1 minus Herfindahl index of premiums written across 56 geographic areas. This measure is generated for proxying the level of insurers' opaqueness (Berry-Stölzle et al., 2012). Base on the same internal capital market hypothesis, we expect that geographical diversification is positively correlated with product diversification.

Organization form

In this study, organizational form ($Stock\_form_{i,t-1}$) is captured by utilizing a dummy variable, specifying 1 for stock insurers and 0 for mutual insurers (Shiu, 2011) since it is an important characteristics of insurance company. According to the view of having access to capital, it is expected that insurers of mutual type tend to diversify more than stock insurers do. Specifically, mutual insurers more prefer to construct an internal capital market mechanism since they possess limited access to capital market than to stock insurers. Based on managerial discretion hypothesis (Mayers and Smith, 1988), it is anticipated that mutual insurers have comparative advantage in operating in the

[65] Since insurers concentrating on few business lines tend to possess the required and specific underwriting knowledge in-house, the real services provided by reinsurers thus tend to improve the underwriting performance of highly diversified insurers (Parlour and Plantin, 2008; Lin, Yu, and Peterson, 2015).

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business lines requiring high level of managerial discretion. Thus, mutual insurers tend to diversify less than stock insurers do.[66] Therefore, we do not have prior expectations on how organization form is related to product diversification.

Firm Age

Firm age ($Firm\_age_{i,t-1}$) is defined as the natural logarithm of the number of years that insurer has been in operation (Berry-Stölzle et al., 2012; Che, Fier, and Liebenberg, 2019). Since insurers with a longer operational history have accumulated many established distribution networks, more product-market knowledge, underwriting experience, and an existing customer-base, they tend to have competitive advantages over new insurers (Giroud and Mueller, 2010; Adams and Jiang, 2016; Xie, Lee, and Eling, 2020). In addition, based on strategic growth hypothesis, an old insurer is prone to face the constraints regarding its product market growth at some time, and thus tends to diversify (Berry-Stölzle et al., 2012). Therefore, we expect that firm age is positively correlated with product diversification.

Group

Group ($Group_{i,t-1}$) is a dummy variable and defined as 1 if the insurer is affiliated to a group, and 0 if the insurer is a standard alone firm (Veprauskaite and Adams, 2018). The insurers affiliated to a group have higher underwriting capacity relative to stand alone insurers since the former tends to possess more access to internal capital markets (ICMs) while unaffiliated insurers only could finance costly external capital (Powell and Sommer, 2008).[67] Therefore, managers of affiliated insurers tend to diversify more to increase their compensation and reputation. Thus, we expect that group is positively associated with product diversification.

3.3 Regression model

The purpose of this essay is to scrutinize whether the tenure of insurer-reinsurer relationship affects product diversification and how firm size mitigates such effects.

[66] Low levels of diversification are required by low level of managerial discretion. On contrary, it is necessary for insurer managers to put more efforts in operating the business with high levels of diversification.

[67] An insurer group can diversify risks by constructing internal capital market within the group (Altuntas and Gößmann, 2016), making its subsidiaries have higher capital buffer to operate.

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Based on the ideas, we specify the following regression model:

$$P\_Div_{i,t} = \beta_0 + \beta_1 \cdot Reins\_Sus_{i,t-1} + \beta_2 \cdot Interaction_{i,t-1} + \beta_3' \cdot CV_{i,t-1} + \varepsilon_{i,t} \quad (4)$$

Where $P\_Div_{i,t}$ indicates total product diversification for insurer i at time t. $Reins\_Sus_{i,t-1}$ denotes the tenure of the insurer-reinsurer relationship for insurer i at time t-1. $Interaction_{i,t-1}$ denotes an interaction term, which is acquired by multiplying reinsurance sustainability by firm size. Regarding the coefficients, β_0 is an intercept term. β_1 measures the average effect of the tenure of insurer-reinsurer relationship on product diversification. If the coefficient shows positive and significance, it provides evidence supporting hypothesis 1. β_2 measures the average effect of interaction term on product diversification. If this coefficient presents negative and significance, providing support for hypothesis 2. $CV_{i,t-1}$ represents a vector of control variable, including firm size, reinsurance, stock investment, geographical diversification, organization form, firm age and group. We specify a lead-lagged relationship to avoid potential simultaneous causality problem (Andreou, Andreou, and Lambertides, 2021). All independent variables are lagged 1 year for controlling possible endogeneity (Géczy, Minton, and Schrand, 1997).

Prior diversification literature on the determinants of product diversification mainly utilize ordinary least squares (OLS) regression model as a basic estimation procedure (Aggarwal and Samwick, 2003). Additionally, our dependent variable belongs to a censored data. Another model used for censored data is Tobit regression model (Berry-Stözle et al., 2012). However, we additionally consider the random effects. Therefore, we not only use ordinary least squares (OLS) model but also random effect Tobit (ReTobit) model to investigate the effects of the tenure of insurer-reinsurer relationship on product diversification. Except the dummy variables, all variables are winsorized at the 1 percent level of both tails to mitigate the concern for outliers (Lin et al., 2011). Robust standard deviation is also employed (Wooldridge, 2016).

4. Empirical Results

4.1 Univariate analysis

Table 1 documents the respectively average value, standard deviation, minimum value, median value, and maximum value of each variable specified in this study. Specifically, the values of average and standard deviation of product diversification

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present 0.45570 and 0.35971, respectively.[68] The average values of reinsurance sustainability, $Reins\_sus\_total_{i,t-1}$, $Reins\_sus\_p25_{i,t-1}$, $Reins\_sus\_p50_{i,t-1}$, and $Reins\_sus\_p75_{i,t-1}$ are 1.54782, 1.62323, 1.94135, and 2.28918, indicating that the average year are 1.54782, 1.62323, 1.94135, and 2.28918, respectively. In addition, we find that the average year increases as we include the reinsurance relationship with higher amount of reinsurance premium ceded. The values of standard deviation of reinsurance sustainability are 1.17971, 1.20112, 1.32399, and 1.40884, respectively. In summary, the descriptive value of the variables used in this study are modest after screening.

<Table 2 is inserted here>

To further test the existence of multicollinearity, we compute the variance inflation factor (VIF) for independent variables. Except for the four reinsurance sustainability and the four interaction term variables, the VIF values for other independent variables are under 10, thus, less than the rule of thumb cutoff value of 10 (Kennedy, 1998). However, Studenmund (2001) suggest that we do not have to deal with the multicollinearity problem if the multicollinearity problem does not result in insignificant results. The results present that the coefficients of these two variables are all significantly associated with product diversification. Therefore, we do not have to deal with such problem.

Table 3 presents the Pearson correlation matrix examining the correlation coefficients on the variables examined in this study. $Reins\_sus\_total_{i,t-1}$, $Reins\_sus\_p25_{i,t-1}$, and $Reins\_sus\_p50_{i,t-1}$ are positively and significantly associated with $P\_Div_{i,t}$ at 1% significant level. These results provide primary supports for hypothesis 1. In addition, $Interaction\_T_{i,t-1}$, $Interaction\_p25_{i,t-1}, and\ Interaction\_p50_{i,t-1}$ are positively associated with $P\_Div_{i,t}$ at 1% significant level. The results also provide primary support for hypothesis 2.

<Table 3 is inserted here>

Firm size is positively associated with product diversification at 1% significant level, providing primary support for the notion that larger firms have more resources to expand their business and are prone to meet growth constraints. Reinsurance is found to be positively correlated with product diversification at 1% significant level,

[68] In the study of Berry-Stözle et al. (2012), the average value and standard deviation of product diversification are 0.340 and 0.300, respectively.

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providing primary support indicating that reinsurers provide real service and reinsurance provides higher underwriting capacity for insurers. However, stock investment is negative associated with product diversification at 10% significant level, inconsistent with our expectation. Geographical diversification is found to be positively associated with product diversification at 1 percent level, providing primary support indicating that opaque insurers establish an internal capital market without information asymmetry to reduce the effect concerning external financial constrain. Organizational form is found to be positively associated with product diversification. The results provide primary support indicating that stock insurers have more access to capital market than mutual insurers and thus they tend to diversify more. Firm age is found to be negatively associated with product diversification at 1% level. The result provides primary result indicating that insurer with a longer operational history tend to take focus underwriting strategies for better risk pricing. Group affiliation is also found to be positively correlated with product diversification at 1% level. The result provides primary supports for the notion that insurers affiliated with a group could have access to internal capital markets (ICMs) and have higher underwriting capacity to diversify.

4.2 Multivariate analysis

The regression results of the tenure of insurer-reinsurer relationship on product diversification by using OLS and random effect Tobit models are presented in Table 4, 5, 6, and 7.[69] In addition, we consider two conditions for analysis, with and without year dummy variable to control year effects. The statistics of relevant test are documented in Table 4, 5, 6, and 7. The F values and λ^2 values of the four analysis conditions are found to be statistically significant at 1% level, thereby confirming that the fitted model is better than the null model which is specified without explanatory variables in Table 4, 5, 6, and 7. Additionally, the values of adjusted R^2 value ranges from 0.91096 to 0.91255 in Table 4, 5, 6, and 7. The total number of insurers included in this analysis is 2,081. The White heteroskedasticity-consistent standard errors are also reported. Overall, the model specifications are modest.

<Table 4, 5, 6, and 7 are inserted here>

Regarding our focused results, reinsurance sustainability is positively and

[69] Specifically, we use $Reins\_Sus\_total_{i,t-1}$ as our reinsurance sustainability measure in Table 4, $Reins\_Sus\_p25_{i,t-1}$ in Table 5, $Reins\_Sus\_p50_{i,t-1}$ in Table 6, and $Reins\_Sus\_p75_{i,t-1}$ in Table 7.

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significantly associated with product diversification in all analyses conditions at least 10% significant level in Table 4, 5, 6, and 7. All analyses conditions provide evidences supporting hypothesis 1. The results indicate that insurers with longer tenure tend to diversify more. It suggests that insurers tend to have better loss experience and purchase reinsurance at a lower price, based on asymmetric learning hypothesis, as the relation's duration increases, resulting in higher underwriting capacity. In addition, insurers also could have access to the real serviced provided by reinsurers. The results are likely to be consistent with Garven et al. (2014), indicating that insurers have better financial performance as the tenure of insurer-reinsurer relationship increases since maintaining long-term relationship with reinsurers assist them to engage in underwriting new business lines. These results are not affected by the measures of reinsurance sustainability.

The interaction terms are found to be negatively associated with product diversification at least 10% significant level in Table 4, 5, 6, and 7, consistent with hypothesis 2. The result denotes that due to reinsurance demand is lower for larger insurers and information asymmetry between reinsurers and larger insurer is lower than that between reinsurers and small insurers. Therefore, the effects of the tenure of insurer-reinsure relationship is mitigated as the insurer's size increases. The results may be consistent with the studies focusing on group insurance, denoting that small groups tends to have and make better use of information advantages than large groups do (Cutler, 1994; Monheit and Schone, 2004).

Regarding control variables, reinsurance is found to be positively associated with product diversification at 1% significant level in all conditions, consistent with renting capital hypothesis and real service hypothesis. Specifically, the results indicate that reinsurers provide insurers with expertise and specialized knowledge and insurers have more underwriting capacity by reinsurance. Thus, insurers purchasing high extent reinsurance tend to diversify. Geographical diversification is found to be positively and significantly associated with product diversification at 10% level, supporting internal capital market hypothesis. Age is found to be positively and significant at 1% level associated with product diversification, also consistent with Berry-Stölzle et al. (2012) and strategic growth hypothesis. The results indicate that insurers with a longer operational history have accumulated many established distribution networks, more product-market knowledge, and an existing customer-base. In addition, they tend to

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diversify more to mitigate binding growth constraints in its product markets. Group affiliation is found to be significant at 1% significant level and positive correlated with product diversification. The results supporting the notion that insurers affiliated with a group tend to diversify more since they could enhance their underwriting capacity from the internal capital market.

4.3Reserve causality testing

Our baseline regression relies on lead-lagged relationship as a first step to handle the reverse causality issues. Specifically, we first specify four reinsurance sustainability measured in year t-1 and use them to estimate product diversification in the subsequent year t. Andreou et al. (2021) indicate another way to examine whether dynamic reserve causality exists in the relationship between reinsurance sustainability and product diversification is to swap the variables of interest. Next, this analysis is conducted by estimating four analysis conditions whether the extent of product diversification in year t-1 is associated with the four reinsurance sustainability measures in year t by using the OLS regression model.

Table 8 documents the results of this analysis. Except the condition when the dependent variable is $Reins\_sus\_total_{i,t}$, product diversification in year t-1 is not associated with $Reins\_sus\_p25_{i,t}$, $Reins\_sus\_p50_{i,t}$, and $Reins\_sus\_p75_{i,t}$, respectively. Overall, the results denote that the past values of product diversification are not significantly correlated with the tenure of insurer-reinsurer relationship. Specifically, our results provide support that the reinsurance sustainability-product diversification relationship cannot be explained by reverse causality.

<Table 8 is inserted here>

5. Robust analysis

Regarding the product diversification measures, in this section, we additionally consider two business lines in constructing the product diversification measure. Although we employ the standard way and follow the literature to construct, there still some business lines are ignored in the calculation of diversification. Specifically, excess worker's compensation and warranty business lines are not included in calculating the product diversification measure. Therefore, in this section, we additionally include the two business lines in constructing the product diversification measures, including 26

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business lines.

Table 9 documents the results of the product diversification of 26 business lines. The variable specification is the same as equation (4). In addition, we only consider the condition including year dummies to capture the year effects. The regression model used in this section is ordinary least squares (OLS) model. All relevant tests are the same as the results in Table 4, 5, 6, and 7 and show moderate. The main results show that the four reinsurance sustainability variables are all positively and significantly associated with product diversification constructed from 26 business lines at 10% significant level, providing evidences supporting hypothesis 1. In addition, the four interaction terms are all negatively and significantly associated with product diversification at 10% significant level. The results also provide evidences supporting hypothesis 2. Overall, the reinsurance sustainability-product diversification relationship could not be influenced by how the product diversification measure is constructed.

<Table 9 is inserted here>

6. Conclusion Remarks

We proceed in this study from determining whether the tenure of insurer-reinsurer relationship is related to product diversification. Using 2012-2020 NAIC database on a sample of US property-casualty insurers, we find that product diversification increases as the level of the tenure of insurer-reinsurer relationship lengthens, consistent with real service hypothesis. In addition, we find that firm size mitigates the effects of the tenure of insurer-reinsurer relationship on product diversification.

The main contribution of this study is to answer how the improvement of efficiency of reinsurance market affects insurer's underwriting strategies. Maintaining long-term reinsurance relationship benefits insurers to expand their business, especially for smaller insurers. In addition, we improve the traditional reinsurance sustainability measure by taking the amount of reinsurance premium ceded over past 5 years to capture important reinsurance relationship.

Our findings have significant implications for managers of insurer and regulators. Both reinsurance and product diversification are risk management tool and strategy, respectively. Our empirical results indicate that maintaining long-term relationship enables primary insurers to acquire real services provided by reinsurers and purchase

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reinsurance at a lower reinsurance premium to underwrite new business lines. For managers, it is better to maintain long-term relationship with current reinsurers since they could have access to expand their business to increase insurer's performance. For regulators, they could adopt policies encouraging primary insurers to maintaining long-term relationship with reinsurers to mitigate the information asymmetry and further to promote them to underwrite new business. The results enable policymakers to improve regulations based on long-term relationship.

Additionally, the empirical results of this study also provide additional supports for why maintain long-term relationship with reinsurers enhances financial performance since the insurers could have the access to diversify their business as the tenure of insurer-reinsurer relationship lengthens. On the contrary, those insurers that frequently switch ceded business to other reinsurers tend to take focus strategy to decrease underwriting risk due to the concern for excess overall underwriting risk, resulting in worsening financial performance.

Future research could extend by investigating how the tenure of insurer-reinsurer relationship affects other types of diversification. For example, future research could investigate how such tenure affects geographical diversification, related, and unrelated diversification. In addition, future research should consider how the tenure of insurer-reinsurer relationship affects the asset-side risk to further take asset risk into account. Therefore, future research may provide a more detail underlying mechanism how the tenure of insurer-reinsurer relationship affects underwriting risk and asset risk simultaneously.

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Table 1: Variable names and definitions

Variables	Predictions	Definitions
Dependent variable		
$P\_Div_{i,t}$		1 minus the sum of the squares of the ratio of the dollar amount of net premium written in a particular line of insurance to the dollar amount of net premium written across all 24 lines of insurance.
Independent variable		
$P\_Div_{i,t-1}$	(+)	It is 1-year lagged of product diversification, $P\_Div_{i,t}$.
$Reins\_Sus\_total_{i,t-1}$	(+)	A measure of reinsurance sustainability. It is defined as the ratio of the mean value of the reinsurance relationship count distribution divided by the standard deviation of the reinsurance relationship count distribution plus 1. In addition, this variable is calculated by including all reinsurance relationship transactions.
$Interaction\_T_{i,t-1}$	(-)	It is an interaction term. Specifically, it is defined as $Reins\_sus\_total_{i,t-1}$ multiply by $Firm\ size_{i,t-1}$.
$Reins\_Sus\_p25_{i,t-1}$	(+)	A measure of reinsurance sustainability. It is defined as the ratio of the mean value of the reinsurance relationship count distribution divided by the standard deviation of the reinsurance relationship count distribution plus 1. In addition, this variable is calculated by including the reinsurance relationship transactions whose values are larger than the value of 25th percentile of all reinsurance relationships.
$Interaction\_p25_{i,t-1}$	(-)	It is an interaction term. Specifically, it is defined as $Reins\_sus\_p25_{i,t-1}$ multiply by $Firm\ size_{i,t-1}$.
$Reins\_Sus\_p50_{i,t-1}$	(+)	A measure of reinsurance sustainability. It is defined as the ratio of the mean value of the reinsurance relationship count distribution divided by the standard deviation of the reinsurance relationship count distribution plus 1. In addition, this variable is calculated by including the reinsurance relationship transactions whose values are larger than the value of 50th percentile of all reinsurance relationships.
$Interaction\_p50_{i,t-1}$	(-)	It is an interaction term. Specifically, it is defined as $Reins\_sus\_p50_{i,t-1}$ multiply by

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		$Firm\ size_{i,t-1}$.
$Reins\_Sus\_p75_{i,t-1}$	(+)	A measure of reinsurance sustainability. It is defined as the ratio of the mean value of the reinsurance relationship count distribution divided by the standard deviation of the reinsurance relationship count distribution plus 1. In addition, this variable is calculated by including the reinsurance relationship transactions whose values are larger than the value of 75^{th} percentile of all reinsurance relationships.
$Interaction\_p75_{i,t-1}$	(-)	It is an interaction term. Specifically, it is defined as $Reins\_sus\_p75_{i,t-1}$ multiply by $Firm\ size_{i,t-1}$.
$Firm\_size_{i,t-1}$	(+)	It is calculated as the natural logarithm of net admitted assets at time t-1.
$Reins_{i,t-1}$	(+)	It is calculated as the ratio of the value of affiliated reinsurance ceded plus the value of non-affiliated reinsurance ceded at time t-1 divided by the value of direct business written plus reinsurance assumed at time t-1.
$Stock\_inv_{i,t-1}$	(+)	It is calculated as the ratio of the value of common stock investments at time t-1 divided by the value of invested assets at time t-1.
$G\_Div_{i,t-1}$	(+)	It is calculated as the sum of the squares of the ratio of the dollar amount of direct business in state j at time t-1 to the total amount of direct business across all states at time t-1.
$Stock\_form_{i,t-1}$	(-)	It is defined as 1 for stock form insurers, and 0 for mutual form insurers at time t-1.
$Firm\_age_{i,t-1}$	(+)	It is calculated as the natural logarithm of the number of years insurer has been in operation at time t-1.
$Group_{i,t-1}$	(+)	It equals 1 if the insurer is affiliated, and 0 if it is non-affiliated

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Table 2: Descriptive analysis

Variables	Mean	S.D.	Min	25^{th}	Median	75^{th}	Max	Obs
Dependent variable								
$P\_Div_{i,t}$	0.45570	0.35971	0.00000	0.02606	0.51199	0.74454	1.00000	15,689
Independent variable								
$P\_Div_{i,t-1}$	0.44747	0.35270	0.00000	0.02563	0.50831	0.73067	1.00000	13,323
$Reins\_Sus\_total_{i,t-1}$	1.54782	1.17971	0.66555	0.91960	1.10605	1.44040	5.00000	13,323
$Interaction\_T_{i,t-1}$	28.54695	21.62350	9.69647	16.81313	20.84985	27.45106	114.63380	13,323
$Reins\_Sus\_p25_{i,t-1}$	1.62323	1.20112	0.66946	0.95114	1.16104	1.56143	5.00000	13,323
$Interaction\_p25_{i,t-1}$	29.95093	22.07613	9.79568	17.31153	21.98950	29.72523	114.63380	13,323
$Reins\_Sus\_p50_{i,t-1}$	1.94135	1.32399	0.67423	1.03727	1.39102	2.07263	5.00000	13,323
$Interaction\_p50_{i,t-1}$	35.74661	24.24653	9.79568	19.23181	26.22891	40.00200	115.18200	13,323
$Reins\_Sus\_p75_{i,t-1}$	2.28918	1.40884	0.66667	1.19165	1.70590	3.00000	5.00000	13,323
$Interaction\_p75_{i,t-1}$	42.11794	25.74083	9.79568	22.26367	32.51453	57.26245	115.18200	13,323
$Firm\_size_{i,t-1}$	18.52044	1.80332	14.24537	17.17707	18.45107	19.73684	23.29952	13,323
$Reins_{i,t-1}$	0.47881	0.33210	0.00000	0.16995	0.44777	0.77897	1.00000	13,323
$Stock\_inv_{i,t-1}$	0.12630	0.16768	0.00000	0.00000	0.05527	0.20123	0.77732	13,323
$G\_Div_{i,t-1}$	0.45605	0.39095	0.00000	0.00000	0.50005	0.86456	0.96501	13,323
$Stock\_form_{i,t-1}$	0.76799	0.42212	0.00000	1.00000	1.00000	1.00000	1.00000	13,323
$Firm\_age_{i,t-1}$	3.50815	0.99181	0.00000	2.99573	3.55534	4.18965	5.18738	13,323
$Group_{i,t-1}$	0.72911	0.44443	0.00000	0.00000	1.00000	1.00000	1.00000	13,323

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Table 3: Pearson correlation matrix

Panel A:

	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)
(a)	-										
(b)	0.954***	-									
(c)	0.047***	0.045***	-								
(d)	0.056***	0.055***	0.987***	-							
(e)	0.037***	0.035***	0.976***	0.963***	-						
(f)	0.046***	0.044***	0.960***	0.975***	0.986***	-					
(g)	0.027***	0.028***	0.817***	0.804***	0.840***	0.826***	-				
(h)	0.036***	0.037***	0.808***	0.821***	0.833***	0.845***	0.985***	-			
(i)	-0.002	-0.001	0.691***	0.677***	0.714***	0.699***	0.853***	0.838***	-		
(j)	0.007	0.009	0.684***	0.697***	0.710***	0.722***	0.841***	0.857***	0.983***	-	
(k)	0.062***	0.063***	-0.056***	0.074***	-0.052***	0.082***	-0.087***	0.057***	-0.110***	0.048***	-
(l)	0.410***	0.409***	0.147***	0.128***	0.136***	0.115***	0.126***	0.105***	0.088***	0.065***	-0.176***
(m)	-0.016*	-0.011	-0.073***	-0.060***	-0.068***	-0.054***	-0.074***	-0.060***	-0.070***	-0.054***	0.158***
(n)	0.194***	0.193***	-0.003	0.058***	-0.013	0.050***	-0.042***	0.027***	-0.070***	0.005	0.461***
(o)	0.024***	0.018**	0.052***	0.072***	0.041***	0.060***	0.016***	0.040***	-0.003	0.021**	0.106***
(p)	0.226***	0.232***	0.005	0.029***	0.014***	0.038***	0.026***	0.052***	0.049***	0.076***	0.205***
(q)	0.295***	0.290***	0.046***	0.090***	0.039***	0.085***	0.012	0.063***	-0.017**	0.040***	0.330***

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Table 3: Pearson correlation matrix (continued).

Panel B						
	(l)	(m)	(n)	(o)	(p)	(q)
(l)	-					
(m)	-0.232***	-				
(n)	0.161***	0.044***	-			
(o)	0.265***	-0.266***	0.274***	-		
(p)	-0.114***	0.262***	0.134***	-0.339***	-	
(q)	0.340***	-0.043***	0.315***	0.319***	-0.012	-

Note: 1. (a) $P\_Div_{i,t}$, (b) $P\_Div_{i,t-1}$, (c) $Reins\_Sus\_total_{i,t-1}$, (d) $Interaction\_T_{i,t-1}$, (e) $Reins\_Sus\_p25_{i,t-1}$, (f) $Interaction\_p25_{i,t-1}$, (g) $Reins\_Sus\_p50_{i,t-1}$, (h) $Interaction\_p50_{i,t-1}$, (i) $Reins\_Sus\_p75_{i,t-1}$, (j) $Interaction\_p75_{i,t-1}$, (k) $Firm\_size_{i,t-1}$, (l) $Reins_{i,t-1}$, (m) $Stock\_inv_{i,t-1}$, (n) $G\_Div_{i,t-1}$, (o) $Stock\_form_{i,t-1}$, (p) $Firm\_age_{i,t-1}$, (q) $Group_{i,t-1}$.

2. ***, **, * represent statistical significance at 0.01, 0.05, and 0.1 levels, respectively.

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Table 4: Effects of the tenure of insurer-reinsurer relationship ($Reins\_Sus\_total$) on product diversification

	Dependent variable: $P\_Div_{i,t}$							
Models	OLS				Random effect Tobit model			
Variables	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
Constant	-0.027	(0.017)	-0.025	(0.017)	-0.027	(0.017)	-0.025	(0.017)
$P\_Div_{i,t-1}$	0.943***	(0.004)	0.939***	(0.004)	0.943***	(0.003)	0.939***	(0.003)
$Reins\_Sus\_total_{i,t-1}$	0.021**	(0.009)	0.017*	(0.009)	0.021***	(0.008)	0.018**	(0.007)
$Firm\_size_{i,t-1}$	0.001	(0.001)	0.001	(0.001)	0.001	(0.001)	0.001	(0.001)
$Interaction\_T_{i,t-1}$	-0.001**	(0.000)	-0.001**	(0.000)	-0.001***	(0.000)	-0.001**	(0.000)
$Reins_{i,t-1}$	0.020***	(0.004)	0.017***	(0.004)	0.020***	(0.003)	0.017***	(0.003)
$Stock\_inv_{i,t-1}$	-0.008*	(0.004)	-0.005	(0.005)	-0.008	(0.005)	-0.005	(0.005)
$G\_Div_{i,t-1}$	0.004*	(0.002)	0.004*	(0.002)	0.005*	(0.003)	0.005*	(0.002)
$Stock\_form_{i,t-1}$	-0.001	(0.001)	-0.000	(0.001)	-0.001	(0.002)	-0.000	(0.002)
$Firm\_age_{i,t-1}$	0.003***	(0.001)	0.004***	(0.001)	0.004***	(0.001)	0.004***	(0.001)
$Group_{i,t-1}$	0.011***	(0.002)	0.011***	(0.002)	0.012***	(0.002)	0.011***	(0.002)
Year dummy	No		Yes		No		Yes	
N	13,323		13,323		13,323		13,323	
Firms	2,081		2,081		2,081		2,081	
Adjusted R^2	0.91097		0.91254					
F value (p value)	13134.46747***(0.00000)		9852.53482***(0.00000)					
λ^2 value (p value)					136441.98374***(0.00000)		132289.17890***(0.00000)	

Note: ***, **, * represent statistical significance at 0.01, 0.05, and 0.1 levels, respectively.

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Table 5: Effects of the tenure of insurer-reinsurer relationship ($Reins\_Sus\_p25$) on product diversification

	Dependent variable: $P\_Div_{i,t}$							
Models	OLS				Random effect Tobit model			
Variables	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
Constant	-0.027	(0.017)	-0.026	(0.017)	-0.027	(0.017)	-0.026	(0.017)
$P\_Div_{i,t-1}$	0.943***	(0.004)	0.939***	(0.004)	0.943***	(0.003)	0.939***	(0.003)
$Reins\_Sus\_p25_{i,t-1}$	0.020**	(0.009)	0.017**	(0.008)	0.020**	(0.008)	0.017**	(0.007)
$Firm\_size_{i,t-1}$	0.001	(0.001)	0.001	(0.001)	0.001	(0.001)	0.001	(0.001)
$Interaction\_p25_{i,t-1}$	-0.001**	(0.000)	-0.001**	(0.000)	-0.001**	(0.000)	-0.001**	(0.000)
$Firm\_size_{i,t-1}$	0.021***	(0.004)	0.017***	(0.004)	0.021***	(0.003)	0.017***	(0.003)
$Reins_{i,t-1}$	-0.008*	(0.005)	-0.006	(0.005)	-0.008	(0.006)	-0.006	(0.005)
$Stock\_inv_{i,t-1}$	0.005*	(0.003)	0.005*	(0.003)	0.005*	(0.003)	0.004*	(0.002)
$G\_Div_{i,t-1}$	-0.001	(0.002)	-0.001	(0.001)	-0.001	(0.003)	-0.001	(0.002)
$Stock\_form_{i,t-1}$	0.004***	(0.001)	0.004***	(0.001)	0.004***	(0.001)	0.004***	(0.001)
$Firm\_age_{i,t-1}$	0.012***	(0.002)	0.011***	(0.002)	0.012***	(0.002)	0.011***	(0.002)
Year dummy	No		Yes		No		Yes	
N	13,323		13,323		13,323		13,323	
Firms	2,081		2,081		2,081		2,081	
Adjusted R^2	0.91097		0.91255					
F value (p value)	13160.56446***(0.00000)		9857.43581***(0.00000)					
λ^2 value (p value)					136437.67252***(0.00000)		132291.44390***(0.00000)	

Note: ***, **, * represent statistical significance at 0.01, 0.05, and 0.1 levels, respectively.

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Table 6: Effects of the tenure of insurer-reinsurer relationship ($Reins\_Sus\_p50$) on product diversification

	Dependent variable: $P\_Div_{i,t}$							
Models	OLS				Random effect Tobit model			
Variables	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
Constant	-0.023	(0.019)	-0.021	(0.018)	-0.023	(0.018)	-0.022	(0.018)
$P\_Div_{i,t-1}$	0.943***	(0.004)	0.939***	(0.004)	0.943***	(0.003)	0.939***	(0.003)
$Reins\_Sus\_p50_{i,t-1}$	0.015*	(0.008)	0.012	(0.008)	0.015**	(0.007)	0.012*	(0.007)
$Firm\_size_{i,t-1}$	0.001	(0.001)	0.001	(0.001)	0.001	(0.001)	0.001	(0.001)
$Interaction\_p50_{i,t-1}$	-0.001**	(0.000)	-0.001*	(0.000)	-0.001**	(0.000)	-0.001*	(0.000)
$Reins_{i,t-1}$	0.022***	(0.004)	0.018***	(0.004)	0.022***	(0.003)	0.018***	(0.003)
$Stock\_inv_{i,t-1}$	-0.009**	(0.004)	-0.006	(0.004)	-0.008	(0.006)	-0.006	(0.006)
$G\_Div_{i,t-1}$	0.005*	(0.003)	0.005*	(0.003)	0.005*	(0.003)	0.005*	(0.003)
$Stock\_form_{i,t-1}$	-0.001	(0.001)	-0.000	(0.001)	-0.001	(0.002)	-0.000	(0.003)
$Firm\_age_{i,t-1}$	0.004***	(0.001)	0.004***	(0.001)	0.004***	(0.001)	0.004***	(0.001)
$Group_{i,t-1}$	0.012***	(0.002)	0.012***	(0.002)	0.012***	(0.002)	0.012***	(0.002)
Year dummy	No		Yes		No		Yes	
N	13,323		13,323		13,323		13,323	
Firms	2,081		2,081		2,081		2,081	
Adjusted R^2	0.91096		0.91254					
F value (p value)	13116.17513***(0.00000)		9830.70565***(0.00000)					
λ^2 value (p value)					136429.74168***(0.00000)		132290.16873***(0.00000)	

Note: ***, **, * represent statistical significance at 0.01, 0.05, and 0.1 levels, respectively.

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Table 7: Effects of the tenure of insurer-reinsurer relationship ($Reins\_Sus\_p75$) on product diversification

	Dependent variable: $P\_Div_{i,t}$							
Models	OLS				Random effect Tobit model			
Variables	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
Constant	-0.027	(0.020)	-0.023	(0.020)	-0.027	(0.020)	-0.023	(0.020)
$P\_Div_{i,t-1}$	0.943***	(0.004)	0.939***	(0.004)	0.943***	(0.003)	0.939***	(0.003)
$Reins\_Sus\_p75_{i,t-1}$	0.015**	(0.007)	0.012	(0.007)	0.015**	(0.007)	0.012*	(0.007)
$Firm\_size_{i,t-1}$	0.001	(0.001)	0.001	(0.001)	0.001	(0.001)	0.001	(0.006)
$Interaction\_p75_{i,t-1}$	-0.001**	(0.000)	-0.001*	(0.000)	-0.001**	(0.000)	-0.001*	(0.000)
$Reins_{i,t-1}$	0.021***	(0.004)	0.018***	(0.004)	0.021***	(0.003)	0.018***	(0.003)
$Stock\_inv_{i,t-1}$	-0.009**	(0.005)	-0.006	(0.005)	-0.009	(0.006)	-0.006	(0.006)
$G\_Div_{i,t-1}$	0.005*	(0.003)	0.005*	(0.003)	0.005*	(0.003)	0.005*	(0.003)
$Stock\_form_{i,t-1}$	-0.000	(0.002)	-0.000	(0.002)	-0.001	(0.003)	-0.000	(0.003)
$Firm\_age_{i,t-1}$	0.004***	(0.001)	0.004***	(0.001)	0.004***	(0.001)	0.004***	(0.001)
$Group_{i,t-1}$	0.012***	(0.002)	0.012***	(0.002)	0.012***	(0.003)	0.012***	(0.002)
Year dummy	No		Yes		No		Yes	
N	13,323		13,323		13,323		13,323	
Firms	2,081		2,081		2,081		2,081	
Adjusted R^2	0.91097		0.91255					
F value (p value)	13148.19938***(0.00000)		9812.71119***(0.00000)					
λ^2 value (p value)					136437.57698***(0.00000)		132297.24065***(0.00000)	

Note: ***, **, * represent statistical significance at 0.01, 0.05, and 0.1 levels, respectively.

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Table 8: Reverse causality testing

Dependent variable:	$Reins\_Sus\_total_{i,t}$		$Reins\_Sus\_p25_{i,t}$		$Reins\_Sus\_p50_{i,t}$		$Reins\_Sus\_p75_{i,t}$	
Model	OLS							
Variables	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
$P\_Div_{i,t-1}$	0.073**	(0.036)	0.042	(0.037)	0.040	(0.040)	-0.029	(0.042)
Control variables	Yes		Yes		Yes		Yes	
Year dummy	Yes		Yes		Yes		Yes	
N	13,323		13,323		13,323		13,323	
Firms	2,081		2,081		2,081		2,081	
Adjusted R^2	0.04794		0.04522		0.05074		0.05462	
F value (p value)	35.12752***(0.00000)		33.54286***(0.00000)		44.15018***(0.00000)		52.82896***(0.00000)	

Note: ***, **, * represent statistical significance at 0.01, 0.05, and 0.1 levels, respectively.

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Table 9: Robust testing

	Dependent variable: $P\_Div_{i,t}$							
Models	OLS							
Variables	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
$Reins\_Sus\_total_{i,t-1}$	0.018**	(0.009)						
$Interaction\_T_{i,t-1}$	-0.001**	(0.000)						
$Reins\_Sus\_p25_{i,t-1}$			0.018**	(0.008)				
$Interaction\_p25_{i,t-1}$			-0.001**	(0.000)				
$Reins\_Sus\_p50_{i,t-1}$					0.013*	(0.007)		
$Interaction\_p50_{i,t-1}$					-0.001**	(0.000)		
$Reins\_Sus\_p75_{i,t-1}$							0.0125*	(0.007)
$Interaction\_p75_{i,t-1}$							-0.001*	(0.000)
Control variables	Yes		Yes		Yes		Yes	
Year dummy	Yes		Yes		Yes		Yes	
N	13,323		13,323		13,323		13,323	
Firms	2,081		2,081		2,081		2,081	
Adjusted R^2	0.91249		0.91249		0.91249		0.91249	
F value (p value)	9880.69237***(0.00000)		9883.51402***(0.00000)		9850.11470***(0.00000)		9842.54692***(0.00000)	

Note: ***, **, * represent statistical significance at 0.01, 0.05, and 0.1 levels, respectively.

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Essay 3

The Effects of the Tenure of Insurer-reinsurer Relationship on Insurer's Market Share: Evidence from the US Property-casualty Insurance Industry

Abstract

Prior studies on asymmetric learning in reinsurance market are scarce and focus on the effects of the tenure of insurer-reinsurer relationship affects financial performance. However, no studies use the non-linearly specification to capture the effects under various level of insurer-reinsurer relationship. In addition, the traditional reinsurance sustainability measure may not capture the intrinsic relationship since it includes all reinsurance transactions but non-important reinsurance relationship may bias the results. In sum, to fill the gap, we scrutinize the effects of the tenure of insurer-reinsurer relationship on insurer's market share in U.S. property-casualty insurance industry by employing NAIC database covering the year from 2012 to 2020. In addition, we improve the reinsurance sustainability measure by taking the amount of reinsurance premium ceded over past 5 years into account to capture various important reinsurance relationship. The result shows that the tenure of insurer-reinsurer relationship is inverted U-shaped related to market share, consistent with asymmetric learning hypothesis. Therefore, we conclude that long-term relationship in reinsurance market plays an important role, in competitive market, in impacting product-market outcomes. The evidences provided by this essay may further provide various implications for practitioners, regulators, reinsurers, insurers, and policyholders.

Keywords: The tenure of insurer-reinsure relationship, Market share, Inverted U-shaped relationship, Asymmetric learning hypothesis, Property-casualty insurance industry

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1. Introduction

Recently, insurance and finance literature begin to form the concept that product-market is an indispensable part in the daily operations when engaging in decisions of risk management (e.g. Harris and Raviv, 1991; Froot et al., 1993; Adam et al., 2007). Additionally, investigating what the factors having an influence on market share (strategic performance) become an important issue since market share reflects the ability of insurer's underwriting and the perception from the view of customers on the insurers and it is also considered the competitiveness of that insurer (Chang, 2019). Recent trend shows that the total annual losses shows an increasing trend since the frequency and severity of insurance losses due to environmental perils increases (Upreti et al., 2021). However, the rising catastrophe losses can deteriorate the capital adequacy of insurers to underwrite and expand and new business at premium with competitive rates and to provide the claim service of the incumbent customers (Froot, 1999). Hence, such increasing trend may give a rise to the insurer's insolvency risk and deteriorate underwriting profitability. In addition, reinsurance could mitigate the concern of the problem of inadequate capital when certain environmental perils occur and further mitigate the concerns of policyholders to the insurers. Therefore, it is an interesting issue for managers, reinsurers, regulators, and others to understand the long-term relationship between reinsurers and insurers, reinsurance (risk management) and reinsurance pricing in the insurance industry and the implications for firm's strategic performance, market share.

In addition, market share is concerned by many stakeholders. For example, higher market share is one of the goals pursued by managers of primary insurers since it indicates high competitiveness (Chang, 2019) and market power (Edeling and Himme, 2018), based on market power theory. As far as the regulators are concerned, they concern that whether the primary insurers adopt cash flow underwriting strategies to pursue the goal of high market share without using appropriate risk transfer, resulting in eroding the profitability and further the solvency. For reinsurers, high market share may denote high reinsurance demand of insurers. However, it may also indicate Therefore, what factors affect market share is an interesting issue for and concerned by various stakeholders in insurance market.

Reinsurance is costly (Cummins et al., 2021) and the efficiency of reinsurance market relies on long-term relationship between reinsurers and insurers since information

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asymmetry and asymmetric learning exists in US property-casualty reinsurance industry (Doherty and Smetters, 2005; Garven et al., 2014).[70] The tenure of insurer-reinsurer relationship mitigates information asymmetry since the information concerning the ceded business gradually revealed over time. Specifically, the long-term implicit contracts between reinsurance and insurers allow the inclusion of new information into reinsurance pricing (Jean-Baptiste and Santomero, 2000).[71] Thus, the reinsurers charge lower reinsurance prices (premiums) for insurers renewing the ceded business (Cohen, 2012). In addition, insurer remain within the insurer-reinsurer relationship tend to have better credit quality (Garven et al., 2014). Therefore, whether tenure of insurer-reinsurer relationship provides insurers comparative advantage in terms of insurance price than rivals in the insurance market is an important issue for academic and practitioners.

Reinsurance is a contingent contract written by reinsurers that indemnify the insurer when events specified in reinsurance contract occurs (Doherty and Tinic, 1981; Upreti and Adams, 2015). It is traditionally used by property-casualty insurers and is considered an inalienable part of the daily operation for an insurer (Shiu, 2016). Reinsurance is generally regarded as a hedging tool since it could hedge the uncertainties resulting from line-of-business (Shiu, 2020), alleviate agency problems between managers and policyholders, such as the underinvestment incentive (e.g. see Garven and MacMinn, 1993), protect insurers from suffering huge losses from catastrophes, reduce insolvency risk of cedants by limiting claim liabilities and further stabilizing loss experience, (Niehaus and Mann, 1992) and enhance their competitiveness (Chang, 2019). In addition, the reasons why primary insurers purchase reinsurance may include the mitigation of policyholders' concerns about insurer insolvency and reduce expected tax liability (Shiu, 2011). Other reasons may include obtaining expertise/ real services provided by reinsurers (Anand, Leverty, and Wunder, 2020). Therefore, the present study intend to combined both strands to examine how long-term relationship in reinsurance market influences product-market share under the various level of relationship’s duration.

Prior theoretical and empirical studies focus less on the issue of long-term

[70] Regarding the reinsurance price (premium), Froot (2001) finds that insurers pay higher reinsurance price many times more than the actuarial fair price.

[71] According to the asymmetric learning hypothesis, the reinsurers would charge repeated reinsurance contracting insurers lower (favorable) reinsurance price, but they charge higher reinsurance price for cedants switching to other reinsurers.

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relationship in reinsurance market although it is well known that the efficiency of reinsurance market relies on long-term relationship. Specifically, theory of Jean-Baptiste and Santomero (2000) indicates that new information is included into reinsurance pricing by long-term implicit contracts.[72] Regarding the development of reinsurance information asymmetry literature, studies mainly investigate whether information asymmetry or asymmetric learning exists. For example, Yan (2013) and Yan and Hong (2015) examine whether information asymmetry between reinsurers and insurers exists in US property-casualty reinsurance industry. Indeed, prior studies demonstrated that a linkage between the tenure of insurer-reinsurer relationship and insurer's financial performance, credit rating, and reinsurance usage theoretically (Jean-Baptise and Santomero, 2000) and empirically (Garven et al., 2014) through the mechanism of asymmetric learning. Prior studies, however, lack evidence on the effect of the tenure of insurer-reinsurer relationship on strategic performance, market share.

Since long-term relationship mitigates information asymmetry between insurers and reinsurers, insurers renewing the reinsurance could purchase reinsurance at a lower (favorable) reinsurance prices (premiums) (Jean-Baptiste and Santemero, 2000). Prior studies mainly investigate whether repeated policyholders have lower risk. However, this study intends to further extend to investigate whether repeated reinsurance contracting affect the strategic position of insurers in the insurance market. Specifically, We answer the questions of whether longer tenure of insurer-reinsurer relationship enables insurers have more comparative advantage over rivals or make them underwrite more conservative. In addition, we further examine whether such effects differ across different levels of relation's duration. Specifically, the higher levels of the tenure of insurer-reinsurer relationship, the lower level of adverse selection, the higher level of monitoring, and the lower levels of reinsurance premium (prices). Hence, it is expected insurer with various relation's duration would have different levels of competitiveness or underwriting strategies.

Our research is motivated in three key regards. Firstly, many information asymmetry studies investigate whether information asymmetry and asymmetric learning exists in various insurance or reinsurance markets. Regarding relation literature on reinsurance

[72] Reinsurance contracts are written in two ways. Specifically, the first is on a "continuous until canceled" basis, and the other is on a "fixed term" basis. Hence, repeated contracting and non-cancellation of a continuous contracts are regarded as long-term implicit contracts. The former indicates that an expiring fixed reinsurance contract is renewed by rolling over into another contract and the latter denotes non-cancellation contracts (Garven et al., 2014).

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market, only Garven et al. (2014) investigate the effects of the tenure of insurer-reinsurer relationship on insurers' return on assets, bankruptcy risk and reinsurance usage. However, until recently, there is no study investigating how the tenure of insurer-reinsure relationship affects product-market output, market share. This study intends to provide reasons and evidences to fill the knowledge gap in the reinsurance literature.

Second, the property-casualty insurance market in US has become a more price competitive market in terms of price and quantity (Chang, 2019). Long-term relationship enables insurers charge lower insurance prices (premiums) for policyholders or customers since they could purchase reinsurance at a lower price. However, the level of monitoring increases as the relation's duration increases since the reinsurers have accumulated more underwriting information. This study is intend to highlight the importance for empirical testing on how the tenure of insurer-reinsure relationship could be maintained to aggressively generate strategic competitive advantages or make them underwrite more conservatively, for example, by allowing insurers to purchase reinsurance at a lower reinsurance prices (premiums) and further reduce insurance prices (premiums) to grow new business or making insurers to operate at a long-term basis to avoid cash flow underwriting or adopt other mispricing strategies. Third, many reinsurance and information asymmetry studies investigate the linear effects of reinsurance (Upreti and Adams, 2015; Yan and Hong, 2015; Chang, 2019). However, their results are not consistent. Therefore, the net effect of the tenure of reinsurer-insurer relationship on strategic performance under various reinsurance level is an empirical issue. Therefore, this study intends to provide new empirical evidence to give another view on the effects of the tenure of insurer-reinsurer relationship on market share.

The present study examines the effects of the tenure of insurer-reinsurer relationship on the ex post product-market position, market share, of insurers. In addition, we further control other firm-specific factors, considered important in prior studies. This study uses National Association of Insurance Commissioners dataset ranging from the year of 2012 to 2020, totaling 9 years. In addition, we use one-step GMM-Difference and GMM-Difference models to handle the dynamic panel data and capture the impacts of the tenure of insurer-reinsurer relationship on market share.

To sum up, the empirical results document that the tenure of insurer-reinsure relationship and market share is inverted U-shaped related. Specifically, the tenure of

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insurer-reinsurer increases market share when the levels of the relation's duration are low. However, the tenure of insurer-reinsurer increases market share when the levels of the tenure of insurer-reinsurer relationship are high. These results indicate that insurers with shorter tenure tend to underwrite more aggressively and grow product-market share at the expense of rivals and tend to switch to other reinsurers for lower reinsurance premium. In addition, they may put less efforts in loss control or risk classification for renewing the reinsurance contracting. However, insurers with longer tenure could be monitored by reinsurers and their opportunity cost of not renewing the reinsurance contracting is higher. Thus, they underwrite more conservatively and avoid cash flow underwriting.

This study is close to Garven et al. (2014). Similarly, we both investigate the effects of the tenure of insurer-reinsurer relationship. However, this study is different from Garven et al. (2014) from many aspects. First, this study investigates the effects of the tenure of insurer-reinsurer relationship on market share, but Garven et al. (2014) examines such effects on bankruptcy risk, reinsurance, return on assets. Specifically, this study investigates the effects on strategic performance but Garven et al. (2014) investigate on financial performance. Second, Garven et al. (2014) investigate the linear effect but this study uses non-linearly specification by including squared term of the tenure of insurer-reinsurer relationship to capture the effects under various levels of the tenure. Third, Garven et al. (2014) find that asymmetric learning exists in reinsurance market, but this study finds that the tenure of insurer-reinsurer relationship is inverted U-shaped related with market share. Specifically, this study further provides evidences on how asymmetric learning affects insurers insurer's strategic performance.

The contribution of this study is twofold. First, this is the first study to examine whether the tenure of insurer-reinsurer relationship influences output market, market share, of insurers to answer the question of how maintaining long-term relationship in reinsurance market affects strategic performance of insurers. Second, this study extends the literature by investing the non-linear relationship and finding that an inverted U-shaped relationship between the tenure of insurer-reinsurer relationship and market share exists since prior reinsurance and information asymmetry literatures mainly investigate linear relationship. Therefore, this study provides another direction for future research to investigate the effects under various the tenure of insurer-reinsurer relationship levels.

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This essay sets out as follows. Next, I introduce the literature associated with our issues and, then, derive a testable hypothesis. Empirical framework, data source, variables are introduced and explained detailed in the subsequent section, and certain empirical results of the estimation analysis by using one-step GMM-system and GMM-difference models are provided thereafter and further explanation are also provided. In addition, we provide reserve causality testing in the final part of this section. The last section offers my concluding remarks.

2. Literature Review and Hypothesis Development

In this section, we will introduce the literature review and develop the testable hypothesis in this study. Specifically, we introduce the literature of information asymmetry and reinsurance to inform readers about the research boundary and research gap. Next, we derive a testable hypothesis regarding the effects of the tenure of insurer-reinsurer relationship on market share to empirically test in the next section.

2.1 Literature Review

In this section, we firstly review reinsurance and information asymmetry literature to find how these studies are developed and what are the research trends, boundaries, and the research gaps to advance the literature.

2.1.1 Reinsurance

Prior studies on reinsurance developed in two streams. The first strand of studies investigates the factors that incentivizing insurers to purchase reinsurance. For example, institutional ownership (Shortridge and Avila, 2004), organization structure (Yanase et al., 2017), CEO turnover (Ho, 2017), risk-based capital regulation implementation (Shiu and Huang, 2015), loss ratio (Shiu and Hsiao, 2014), corporate tax (Adams, Hardwick, and Zou, 2008), country-level factors (Altuntas, Garven, and Rauch, 2018), and demutualization (Wang et al., 2008) are determinants of reinsurance scrutinized in prior reinsurance studies. Second, the other strand of research investigates the effects of reinsurance on various dimensions of ceding insurers. For example, reinsurance lowers performance (Lee and Lee, 2012; Shiu, 2020), reserving errors (Veprauskaite and Adams, 2018), loss reserve errors (Browne et al., 2012), market share (Chang, 2019), liquidity (Chang and Jeng, 2016), cost of equity (Upreti, Adams and Jia, 2021),

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and derivative usage (Shiu, 2016) but increases market share (Upreti and Adams, 2015), solvency (Chen et al., 2001), value (Scordis and Steinorth, 2012) and leverage (Shiu, 2011; Sheikh, Syed and Shah, 2018). Specifically, the main reason for insurers to purchase reinsurance is to obtain real service provided by reinsurers (Anand et al., 2020).

2.1.2 Information asymmetry

Prior studies focusing on information asymmetry in (re)insurance market mainly investigate whether information asymmetry or asymmetric learning exists in certain (re)insurance market. Specifically, information asymmetry indicates that cedants have all information regarding the riskiness of ceded business that reinsurers lack and utilize such information in reinsurance purchasing decisions in the context of reinsurance market. Regarding studies on insurance market, many studies examine whether information asymmetry exists in various types of insurance markets.[73] However, less studies scrutinizing the information asymmetry issues in reinsurance market. For instance, Yan (2013) scrutinized whether residual moral hazard exists in US three largest reinsurance market, respectively. The empirical results document that residual moral hazard does not exist in both the private passenger auto liability and product liability reinsurance markets, but might exist in the homeowners reinsurance market. Yan and Hong (2015) further investigate the existence of information asymmetry in three major reinsurance markets and their empirical results present that asymmetric information problems are present in the private passenger auto liability and homeowners reinsurance markets, but not in the product liability reinsurance market. Chen and Shiu (2020) examine the existence of information asymmetry problem. Their results indicate that information asymmetry problem exists between insurers and reinsurers in Taiwan non-life reinsurance industry. In addition, they find that the source of information asymmetry mainly comes from moral hazard.

Asymmetric learning is another phenomenon that develops recently not only in insurance market but also in reinsurance market. Asymmetric learning denotes that the

[73] For instance, prior studies examining whether information asymmetry exists in private accident insurance market (Spindler, 2015), group critical illness insurance market (Eling, Jia, and Yao, 2017), private long-term care insurance market (Browne and Zhou-Richter, 2014), automobile insurance market (Gao, Powers and Wang, 2017), life insurance market (He, 2009), private health insurance (Olivella and Vera-Hernández, 2013), crop insurance (He et al., 2018), annuity market (Finkelstein and Poterba, 2004) and cancer insurance market (Wang et al., 2011).

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information regarding policyholders' risk types that insurers lack is regarded as private information and such private information may be alleviated by learning over time by insurers (Cohen and Siegelman, 2010). Certain asymmetric learning studies focus on different types of insurance product markets in different countries. For example, Cohen (2012) examine whether Israeli automobile insurance market exists asymmetric learning phenomena. The results provide evidences showing that repeated contracting with the incumbent insurer equips insurance underwriters with informational advantage over other rival insurers. Kofman and Nini (2013) scrutinize contractual relationships in Australian nonlife insurance markets. Although their evidences show that the policyholder’s average risk lowers with a rise of policyholder tenure, such effects are due to observable information. Therefore, the results do not provide evidences supporting asymmetric learning hypothesis. Shi and Zhang (2016) scrutinize whether asymmetric learning exists in Singapore automobile insurance market. Specifically, this market is equipped with the mechanism of partial information sharing among insurers. Their evidences support the existence of asymmetric learning.

Regarding studies on reinsurance markets, as far as authors could reach, we find two studies focus on the issue of asymmetric learning in reinsurance market. First, Jean-Baptiste and Santomero (2000) argue that, as information regarding the ceded business is revealed only over time, long-term implicit contracts between cedants and reinsurers allows reinsurers include the revealed new information into reinsurance pricing. They derive three hypotheses and conclude that the long-term relationship between insurers and reinsurers lead to more reinsurance coverage, higher insurer profits, and lower expected distress for cedants. Using a sample of property-casualty insurers in the US, Garven et al. (2014) further empirically examining whether asymmetric learning exists and further find that the Jean-Baptiste and Santomero (2000)’s hypotheses are supported by these empirical evidences.

Based on the previous literature review, we find that no study investigates how affects market share, ex post output market, of insurers are affected by the tenure of insurer-reinsure relationship. In addition, we also find that prior studies only focusing on the linear effects. Therefore, to advance the literature, we investigate the impacts of the tenure of insurer-reinsurer relationship on market share and examine the non-linear relationship.

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2.2 Hypothesis Development

In this section, we derive a hypothesis about how market share is impacted as the tenure of insurer-reinsurer relationship increases under various levels of duration of reinsurance relationship.

In the presence of information asymmetry between insiders and outsiders at the company level, cost of borrowing and investment opportunity are favorable influenced by risk hedging decision, enabling insurers to achieve competitive benefits at the expense of rivals by lowering cost and/or improving revenues (Campello et al., 2011). Since the US property-casualty insurance industry is regarded by practitioners, academic scholars as a completely competitive market in terms of the number of firms and products provided (Chang, 2019), insurers inherently find ways to acquire competitive advantage over other rivals in insurance markets to enhance market share and keep their solvency level at an appropriate level to fulfill the commitment made to policyholders. With more reinsurance, insurers could have comparative advantages over their rivals and achieve higher market share at the expense of other rivals (Upreti and Adams, 2015) since reinsurance transfer low frequency and high severity risk to reinsurers to enhance insurers' underwriting capacity and capital buffer and customers prefer to purchase safer insurance products from the insurers having higher solvency (Shiu, 2020).[74] Therefore, purchasing reinsurance could affect the market position of insurers.

However, information asymmetry at the reinsurance contract level exists since reinsurance treaty is less formal than insurance treaty (Doherty and Smetters, 2005) and managers have incentives to hide information regarding the risk type of business to pretend them as low-risk business to generate private information that reinsurers lack. In addition, reinsurance brokers may provide poor advice quality within the reinsurance transaction and they tend to engage in opportunistic behaviors for better reinsurance terms and price to acquire higher reinsurance commissions from reinsurers (Marvel, 1982; Gravelle, 1994; Sonnenholzner, Friese, and Schulenburg, 2009). However, information asymmetry deteriorates the efficiency of risk allocation between insurers

[74] In competitive market, the customer will choose the products with the lowest price under the same quality of insurance products or choose the insurance products with the highest quality under the same insurance premium. The primary insurer would cut the insurance price to retain old policyholders and attract new customers since the insurance price cutting will affect the demand of rival insurer's insurance products as rivals' policyholders would switch to the lowest insurance price insurance product producer.

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and reinsurers (Yan and Hong, 2015) and leads to adverse selection or moral hazard phenomenon (Cohen and Siegelman, 2010). Additionally, the greater the adverse selection between cedants and reinsurers, the greater the adverse selection cost, and thus the greater the reinsurance premium (Garven et al., 2014). Moreover, moral hazard may result from the aggressive underwriting strategies adopted by insurers. Specifically, the cost of reinsurance (a hedging tool) and underwriting strategies may be altered with different levels of information asymmetry. Thus, information asymmetry between insurers and reinsurers may affect the market position of insurers.[75]

Reinsurance is traditionally conducted on a basis of long-term relationship (Doherty and Smetters, 2005) since reinsurance contract is not standard as insurance contract. It is assumed that cedants have all information about riskiness of ceded business since cedants underwrite the business directly but reinsurer underwrite indirectly (Jean-Baptiste and Santomero, 2000). Specifically, private information that is used by cedants in reinsurance purchasing decisions may not be attainable for reinsurers in the beginning. Moreover, asymmetric learning exists in US property-casualty reinsurance industry (Garven et al., 2014). Specifically, reinsurers obtain the information that is gradually revealed in terms of claim incurred and thus learn the risk type of business over time to reduce adverse selection and include such revealed information into risk classification and reinsurance pricing.[76,77] Besides, reinsurance premiums charged by reinsurers are based on the riskiness of the past loss experience. Insurers adopt different strategies based on the loss experience of the underwritten business. Specifically, insurers with better loss experience tend to retain with the current reinsurers (reinsurance relationship) for lower reinsurance premium since other reinsurers in the

[75] In this study, we assume that information asymmetry exists in US property-casualty insurance reinsurance industry since Garven et al. (2014) empirically examine whether asymmetric learning exists in US property-casualty insurance reinsurance industry and they find evidence showing that such effects exist. Information asymmetry in insurance market denotes that a buyer of insurance has more private information regarding the buyer's risk that the insurer who underwrites the policy lack and uses such private information in purchasing insurance (Cohen and Siegelman, 2010). In reinsurance market, an insurer also has private information that a reinsurer does not have since an insurer underwrite the business directly but a reinsurer does not underwrite the business directly. Specifically, a reinsurer could only obtain the information concerning the riskiness of ceded business through the acknowledgement from the insurer. Therefore, the reinsure may obtain incomplete information regarding the ceded business.

[76] The existence and persistence adverse selection exists and persists due to the existence of information asymmetry (Rothschild and Stiglitz, 1976). So long as the reinsurance purchaser's information advantage over the reinsurer disappears, adverse selection ceases to exist.

[77] Conventional wisdom in practice and in academic suggests that the efficiency of reinsurance market relies on long-term relationship (Doherty and Smetters, 2005) since reinsurance market is not heavily regulated as the primary insurance market.

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insurance market do not possess the information regarding the real risk of their business over time.[78,79] On contrary, insurers with poor loss experience tend to switch their business to other reinsurers for fleeting their pool records since the current reinsurers charge high reinsurance premium for them to purchase.[80] Therefore, insurers that are renewed by reinsurers tend to be low-risk and those insurers that take advantage of other reinsurers by holding superior information regarding the business risk. Thus, adverse selection between reinsurance contracting parties is gradually mitigated with the increase of the tenure of insurer-reinsurer relationship.[81]

In terms of reinsurers, they monitor the underwriting and claim handling activities of insurers. In addition, the extent of monitoring rises as reinsurance relationship intensifies (Doherty and Smetters, 2005). With more private information revealed over time, the reduced cost of monitoring is significant, enabling reinsurers to reduce reinsurance premiums since the savings of reduced monitoring cost rises as the reinsurance relationship lengthens (Bharath et al., 2011). The opportunity cost of engaging in opportunistic behavior rises with the rise of the tenure of insurer-reinsurer relationship. Thus, moral hazard reduces as such reinsurance relationship lengthens. Therefore, insurers with longer reinsurance relationship tend to have better loss experience and underwrite more prudently. In sum, information asymmetry, adverse

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78 The reinsurer gradually learns the risk type of ceded business after the realization of claims of ceded business and put such information in risk classification and reinsurance pricing. The reinsurer could charge high risk ceded business high reinsurance premium and charge low risk ceded business low reinsurance premium. For cedants ceding low risk ceded business, they will choose the retain the current reinsurer and renew the current reinsurance. For cedants ceding high risk ceded business, they will choose the switch to other reinsurer to fleet their records (Cohen, 2012). The reinsurer tends to renew the reinsurance business and offer lower reinsurance price for repeated contracting cedants since repeated cedants tends to cede low risk business to a reinsurer and they are unable to signal their quality to other reinsurers (Kofman and Nini, 2013).

79 Froot (2001) documented that reinsurers offer insurers for a much higher reinsurance premium. Specifically, it is more than the actuarial price of the business transferred. Specifically, reinsurance is costly (Cummins et al., 2021). Therefore, adverse selection mitigation through repeated reinsurance contracting makes reinsurance premium decrease more and further provide comparative advantage for repeated insurers due to the access of lower cost of risk management tool.

80 Insurers switch high risk ceded business to other reinsurers since they could pretend the ceded business as low risk to purchase reinsurance at a low reinsurance premium compared to the reinsurance premium retained with current reinsurer. The other reinsurer only could charge the ceded business the reinsurance premium corresponding to the average risk since the other reinsurer has no additional underwriting information regarding the quality of the ceded business.

81 Asymmetric learning indicates that the riskiness of the business gradually reveals over time and thus the reinsurer could accumulate and include historical claim records in reinsurance pricing during the reinsurance policy effective period. The information of riskiness concerning ceded business will gradually be revealed after the realization of claim incurred (Kofman and Nini, 2013). Long-term implicit reinsurance contracts allow the inclusion of new information into reinsurance pricing when information is revealed over time (Jean-Baptiste and Santomero, 2000), resulting in more accurate reinsurance price.

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selection, and moral hazard all reduce as the tenure of insurer-reinsurer relationship lengthens since the private information utilized by cedants in reinsurance purchasing mitigates over time.

Since we derive that the tenure of insurer-reinsure relationship is complex inverted U-shaped related with market share, we must discuss the conditions under various levels of reinsurance relationship. That is, managers of insurers with various reinsurance relationship tend to present different attitude in underwriting and have different conditions. First, we discuss the short reinsurance relationship condition. Second, we scrutinize the increasing condition when the level of insurer-reinsurer relationship increases. Finally, we conclude the long reinsurance relationship condition.

At low level of reinsurance relationship, information asymmetry within reinsurance contracting parties tends to be high.[82] Specifically, insurer managers tend to possess more private material information regarding the riskiness of business that reinsurers do not have. Under this circumstance, insurer managers tend to be myopic and subjected to the monitoring by the boards for the short-term goals. Thus, they underwrite more aggressively by lowering underwriting standard, adopt cash flow underwriting strategy, and put less efforts into underwriting activities to grow their business. Their business tends to be composed of new customers, high-risk, and not being renewed by incumbent reinsurers. Thus, they take advantage of switching to other reinsurers by pretending their ceded business as low-risk to purchase reinsurance. Therefore, market share increases as the reinsurance relationship lengthens when the level of the tenure of insurer-reinsurer relationship is short.

As the tenure of insurer-reinsure relationship lengthens, information asymmetry phenomenon is mitigated with a rise in the length of reinsurance relationship since the current reinsurers obtain material private information regarding the riskiness of ceded business that they lack and utilized by insurers in reinsurance purchasing decisions over time. In addition, insurers retaining with current reinsurers are gradually subject to higher extent of monitoring as the level of reinsurance relationship lengthens (Doherty and Smetters, 2005). Besides, insurer managers gradually become more careful and prudent to improve the loss experience to renew the current business. Specifically, low-risk insurers tend to retain with the current reinsurance relationship and further enhance

[82] In the first essay, we have empirically tested and found that information asymmetry increases with the increase of the tenure of insurer-reinsurer relationship at low level of reinsurance relationship.

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underwriting standard and put more efforts in loss mitigation. Therefore, the reduction effect of reinsurance relation's duration on market share increases as the tenure of insurer-reinsurer relationship increases.

At high level of the tenure of reinsurance relationship, information asymmetry phenomenon is significantly reduced. Specifically, the current reinsurers obtain material private information that they lack and that is gradually revealed in terms of claims incurred over time. In addition, low-risk insurers tend to remain within the reinsurance relationship. The extent of monitoring by reinsurers is high at this stage. Thus, insurer managers tend to underwrite prudently by enhancing underwriting standard and put more efforts in loss control to improve loss experience and to renew reinsurance for lower reinsurance premium. In addition, their switching cost to other reinsurers is costly as well. Therefore, market share decreases with the increase of the tenure of insurer-reinsurer relationship when such the length of such relationship is long.

Based on the previous derivations, we conclude that insurers tend to be aggressive in underwriting and thus purchase reinsurance for expanding business or growing new business in the short-term when the length of the duration of reinsurance relationship is short.[83] However, insurers with longer duration of reinsurance relationship tend to be more careful and underwrite prudently to improve loss experience for renewing reinsurance with current reinsurers.[84,85] Thus, we propose the following hypothesis:

Hypothesis: The association between the tenure of insurer-reinsurer relationship and market share is nonlinear, with the slope positive at low levels of the tenure of insurer-reinsure relationship and negative at high levels of the tenure of insurer-

[83] In competitive market, to increase market share, managers could only compete with other rivals by cutting insurance price and operating at a lower cost to retain old low risk policyholders and attract new customers.

[84] In competitive markets, managers of firms purchasing property insurance tend to raise risk-taking for maximizing shareholder value and their self-interests through engaging in aggressive price reducing/output increasing behaviors rather than reduce risk-taking due to the contention of Seog (2006).

[85] Managers of insurers have incentives to pursuit high market share for the following reasons. First, an insurer with high market share has high brand recognition and reputational capital (Hill et al., 2020). Second, based on efficiency theory (EF), firms possessing high market share benefit from experience curve effects, economies of scale, and economies of scope, enabling them to reduce operating or product costs (e.g., Demsetz, 1973; Gale, 1972; Jacobson and Aaker, 1985; Edeling and Himme, 2018). According to market power theory (MP), market power advantage derives from large market share. Specifically, the monopoly/monopsony position of high market share insurers facilitates them to offer high insurance premiums from policyholders and to negotiate lower reinsurance premiums with reinsurers or reinsurance brokers (Boulding and Staelin, 1990). Based on product (service) quality assessment theory (PQ), market share of insurers is regarded as a signal for customers to distinguish good quality from poor quality insurance products (Hellofs and Jacobson, 1999).

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reinsurer relationship.

3. Data, Variables, and Regression models

In this section, we introduce data, variable development and regression models used in this study step by step to give a detailed description of the methodology section.

3.1 Data

Our initial sample includes all property-casualty insurers in the NAIC Infopro database for the years from 2012 to 2020.[86] Our data consists an unbalanced panel data. Initially, the number of property-casualty insurers from 2012 to 2020 are from 3028 to 2853, respectively. Then, we exclude the sample observations that exhibit nonpositive direct premiums written and total net admitted assets. Next, we remove those observations characterizing insurers other than stock or mutual form of organization structure (Berry-Stözle et al., 2012). Finally, we eliminate the firm-year observations if the ratio of reinsurance ceded to the sum of direct premiums written and reinsurance assumed has a value above one or below zero (Shiu, 2011). We follow Mankai and Belgacem (2016) and exclude insurers with regulatory actions in process.[87] Additionally, we exclude insurers that are not domiciled within the United States (Hsu, Huang and Lai, 2015). We exclude insurers considered as reinsurers since their assumed reinsurance business account for more than 75% of total written business (Cole and McCullough, 2006). We also exclude insurers without reinsurance sustainability observation. The final sample observations, after the elimination process, are composed of 11,161 firm-year observations from 2012 to 2020.

The information regarding reinsurance relationship, reinsurance sustainability, on reinsurers' and reinsurance transactions' information for separate reinsurer was gather and consolidated from the NAIC Schedule F–Part 3. Specifically, we collect reinsurers' name and reinsurance premium ceded data.

3.2 Variables

[86] The data of dependent variable covers the years from 2012 to 2020 and the data of independent variables used in this study are from 2011 to 2019.

[87] We remove insurers with the following statuses. First, the insurer is in conservatorship. Second, the insurer is rehabilitated. Third, the insurer is in permanent or temporary receivership. Fourth, the insurer is being liquidated or has been liquidated (Morris et al., 2017).

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In this section, the definitions and meanings of variables used in this study are defined and explained. In addition, how these independent variables respectively influence the dependent variable are derived and explained. Finally, we make our predictions regarding the directions of those effects. All variables are mainly referred from both Chang (2019) and Garven et al. (2014). Table 1 exhibits the abbreviation and definitions of variables.

<Table 1 is inserted here>

3.2.1 Dependent variable

We follow Chang (2019) to include market share ratio as our main dependent variable. The market share ratio is defined as the ratio of an insurer's direct premium written divided by the aggregation of direct premium written of whole industry multiplied by 10,000. The higher the value, the higher the market share. Prior studies have shown that market share enhances a firm's profitability (Park and Srinivasan, 1994) and, from a marketing perspective, higher market share signals higher value for a consumer (O'Regan, 2002) and market share is recognized as a measure of the value delivered to the consumers (Sandvik and Sandvik, 2003) since it is a measure representing the effectiveness-oriented concept of a firm's performance.[88]

3.2.2 Main independent variable

Sustainability and the squared term of Sustainability

Concerning the main independent variables, we follow Garven et al. (2014) and use "reinsurance sustainability index" as our measure for the tenure of the insurer-reinsurer relationship and repeat reinsurance contracting.[89] To create this measure, we adopt the following steps. Firstly, separate 5-year rolling windows were created.[90] Second, the years within every 5-year rolling window, indicating that a cedant cedes business to each of its reinsurers, are calculated. Specifically, we calculate both the mean and standard deviation by using each cedant's reinsurance relationship count distribution.

[88] The relationship between market share and consumer value has been recognized by both academics and practitioners (Gates et al., 2000).

[89] In the following section, we call "reinsurance sustainability" to represent the tenure of insurer-reinsurer relationship.

[90] The rolling windows include the periods of 2007-2011, 2008-2012, 2009-2013, 2010-2014, 2011-2015, 2012-2016, 2013-2017, 2014-2018, and 2015-2019. Therefore, our analysis include 9 rolling windows.

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The reinsurance sustainability ($Reins\_Sus$) is constructed in equation (1).

$$Reins\_Sus = \frac{\text{mean of the reinsurance relationship count distribution}}{(\text{standard deviation of the reinsurance relationship count distribution}+1)} \quad (1)$$

The numerator value ranges from 0 to 5. Within the reasonable value range, the highest value and lowest value for the denominator are 5 and 1, respectively. The former indicates that a cedant purchases reinsurance from the same group of reinsurers over the specified 5-year rolling window, and the latter suggest that a cedant purchases reinsurance from the same group of reinsurers only for 1 year and possibly switches the ceded business to other group of reinsurers. Conceptually, we regard persistency as the average value of the reinsurer relationship count distribution and consistency as the standard deviation of the reinsurer relationship count distribution. The higher (lower) the average value, the higher (lower) the persistency of the reinsurance relationship with a given reinsurer. Moreover, the higher (lower) the standard deviation, the lower (higher) the consistency of the reinsurance relationship with a given reinsurer. In sum, a cedant receiving high value of reinsurance sustainability maintains long-term reinsurance relationship with the same group of reinsurers, indicating that they have not only high persistency but also high consistency. On contrary, a cedants receiving low value of reinsurance sustainability tend to switch their business to other reinsurance counterparties frequently, denoting that they have low value of persistency and consistency. Specifically, reinsurance sustainability represents a proxy for private information about the riskiness of ceded business that reinsurers lack but used by cedants in reinsurance purchasing decisions. Cedants having low (high) value of reinsurance sustainability have superior (less) information advantage over current reinsurers.

However, the above measure may be distorted by non-important reinsurance transactions due to the inclusions of all reinsurance transactions. Specifically, the reinsurance sustainability measure gives all reinsurance transactions equal weighting when calculating the denominator and numerator. Thus, reinsurance transactions with low amount of reinsurance transaction may bias the value of reinsurance sustainability.

Kysucky and Norden (2016) review and summarize that time, distance, exclusivity, and cross-product synergies are the key dimensions of strong relationship. In addition, Donker, Ng, and Shao (2020) use the amount of loans loaned by banks in the past 5 years to construct banking relationship measures. Therefore, we follow these concepts and take the amount of reinsurance premium ceded of the past 5 year's reinsurance

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transactions into account in constructing different reinsurance sustainability measure. First, we calculate the amount of reinsurance premium ceded over the past 5 years on the basis of each reinsurance relationship. For example, the given reinsurance relationship represents the relationship between a cedant i and a given reinsurer j within the specified 5-year rolling window. Next, to capture important reinsurance transaction, we consider reinsurance transaction with large amount of reinsurance premium as the important reinsurance transactions. Therefore, we design 4 scenarios for choosing the observations based on the amount of reinsurance premium ceded over the past 5 years. Then, we generate four reinsurance sustainability variables to emphasize various levels of important reinsurance transaction. In addition, such specification enables us to investigate whether "too-big-to-fail" effect for moral hazard exists if the reinsurance relationship becomes strong.[91]

Next, the reinsurance relation is sorted based on the amount of reinsurance premium ceded over the past 5 years. The first analysis includes all reinsurance transactions as Garven et al. (2014) did. We define the variable name as $Reins\_Sus\_total$. The second analysis excludes the relationship observations whose values are lower than the value of the 25th percentile of all reinsurance relationships and include the other reinsurance relationship observations. Then, we construct the $Reins\_Sus\_p25$ variable. The third analysis excludes the relationship observations whose values are lower than the value of the 50th percentile of all reinsurance relationships and include the other reinsurance relationship observations. Next, we construct the $Reins\_Sus\_p50$ variable. The fourth analysis excludes the observations whose accumulated reinsurance premium lower than the 75th percentile of the accumulated reinsurance premium of overall reinsurance transactions. We construct the $Reins\_Sus\_p75$ variable. In sum, we construct 4 reinsurance sustainability variables, including $Reins\_Sus\_total$, $Reins\_Sus\_p25$, $Reins\_Sus\_p50$, and $Reins\_Sus\_p75$.

In addition, we also create and include the squared term of reinsurance sustainability, $Reins\_Sus^2$, to capture the non-linear effects of the tenure of insurer-reinsurer relationship on loss ratio, combined ratio and underwriting profitability.[92] The

[91] Regarding relationship banking literature, Kysucky and Norden (2016) indicate that a borrower with huge amount of borrowing with banks tend to have incentives to engage in activities resulting in moral hazard in various levels of bank relationships. Specifically, instead of improving their financial condition, the borrower tends to make a gamble by getting more funds from banks.

[92] The empirical method of this study is similar to Kofman and Nini (2013). Kofman and Nini (2013) test the prediction by examining the correlation between the age of a policy and both claim frequency

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variables included in this analysis are $Reins\_Sus\_total^2$, $Reins\_Sus\_p25^2$, $Reins\_Sus\_p50^2$, and $Reins\_Sus\_p75^2$.

Based on hypothesis derived above, we expect that reinsurance sustainability is positive correlated with market share and the squared term of reinsurance sustainability is negatively associated with market share.

Reinsurance and Reinsurance squared

The insurer's reinsurance ratio (Reins) is defined as the ratio of affiliated reinsurance ceded plus non-affiliated reinsurance ceded divided by direct business written plus reinsurance assumed. To capture the non-linear effects of reinsurance, we additionally generate the squared term of reinsurance. Specifically, the higher the reinsurance, the higher level of underwriting capacity, and the high level of monitoring by reinsurers. Thus, we do not make prior expectations on how reinsurance and the squared term of reinsurance on market share.

3.2.3 Control variables

1-year Lagged market share

To alleviate the omitted variable problem, we include 1-year lagged dependent variable as control variable (Wooldridge, 2016). It is expected insurers with higher market share in the previous period exhibit higher market share in the next period. Thus, we expect that market share at time t-1 is positively associated with market share at time t.

Firm size

The natural logarithm of net admitted assets is to proxy an insurer's size (Che and Liebenberg, 2017).[93] Larger firms operate at a lower cost resulting from reduced fixed costs and variable costs based upon the economic scale theory and underwrite many business lines based on the economic scope theory. In addition, larger firms also have higher reputation and more resources. Thus, they spend more resources in advertising to enhance their visibility and thus market share. Therefore, we expect that firm size is

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and claim severity, conditional on other observable variables likely to be correlated with claim risk. However, we do not acquire reinsurance contractual level data. Therefore, we examine the association between reinsurance sustainability and loss ratio, combined ratio, and underwriting profitability.

[93] Pottier and Sommer (1997) point out that the probability distribution regarding insurer's total assets specific to the insurance industry exhibits highly skewed.

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positive correlated with market share.

Financial Leverage

Financial leverage is constructed as the ratio of total liabilities divided by total net admitted assets. Highly-levered insurers tend to exhibit high insolvency probability and bankruptcy cost (Shiu, 2020). From another angle, insurers writing more business relative to their surplus also exhibit high insolvency probability (Lee and Lee, 2012). However, insurers should keep solvency at an acceptable level under the supervision of regulatory authorities. Hence, insurers with higher financial leverage will underwrite less business to keep solvency ratio to a stable level and reduce bankruptcy risk. In addition, capital constrained insurers may find it hard to attract new customers than insurers are in the condition of stronger financial condition (Zanjani, 2002). We expect that financial leverage is negatively correlated with market share.

Operating ratio

Operating ratio is determined by the ratio of loss expense and underwriting expense divided by gross premium written. Weiss (1968) argue that product price lowers as the operating costs reduced, inducing more product purchase. In addition, Khorana and Servaes (2012) denote that firms transacting product at a cheaper fee could enhance their market share position. Therefore, we predict that operating cost is negative associated with market share.

Loss ratio

The loss ratio is defined as the loss incurred and loss adjusted expense divided by premium earned. Loss ratio is thought of an inverse measure of insurance price by many prior studies. Weiss (1968) propose that product price is connected to market share of a firm. A company’s market share drops if it raises its product price and the price lies above the prices set by rival firms in the same market (Dahlby and West, 1986). Hence, we predict that loss ratio is positive associated with market share.

Product Diversification

Product diversification is defined as one minus the ratio of the sum of the squares of the ratio of the dollar amount of direct business written in a certain line of insurance

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divided by the dollar amount of direct business across all 24 lines of insurance. Khorana and Servaes (2012) propose that a firm, in the mutual fund industry, tends to have a higher market share since the firm offer a variety of financial products with wider range and scopes than other rivals could offer. Highly diversified firms have higher market share, also having the access to reach a great many of potential customers (Upreti and Adams, 2015), wherever economies of scope takes effects (Parente et al., 2010). Therefore, we expect that a positive relationship between business diversification and market share is expected.

Geographical diversification

Geographical diversification is defined as the sum of the squares of the ratio of the dollar amount of direct business in state j divided by the total amount of direct business across all states. Insurers operating in various geographical areas tend to possess high market share (Erickson and Finkler, 1985). Highly geographical diversified firms tend to have more access to potential customers in various geographical area. Hence, we expect that geographical diversification is positive related to market share.

Commercial line Ratio

The ratio of commercial line business is defined as the sum of direct premium written of commercial lines divided the sum of direct premium of all lines. Commercial-line business exhibits higher expense ratio than that of personal-line business (Regan, 1999). Hence, based upon the argument proposed by Weiss (1968), a lower market share results from a higher expense ratio. Therefore, we expect that commercial line is positive correlated with market share.

Long-tail line Ratio

Long-tail line ratio is defined as the ratio of the sum of direct premium written of long-tail lines divided the sum of direct premium of all lines. An insurer underwriting high level of long-tail line business tend to exhibit greater uncertainty in terms of higher long-term risk. Kelly et al. (2012) contend that insurers hold higher capital to prepare for the occurrence of adverse event since these insurers have underwritten more long-tail business. Therefore, an insurer would reduce the market share of long-tail lines of business. We expect that the nexus between long-tail line ratio and market share is

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negative.

Stock form

Stock form is measured as a dummy variable, equaling 1 if the insurer exhibits a stock form, and 0 otherwise. Stock form insurers are monitored by shareholders. The managers of insurers carefully underwrite and do not casually expand their business to focus on the lines of business they have expertise in. In contrast, insurers have respective level of risk tolerance based on the organizational form they belonged (Cummins et al., 2001). In addition, stock insurers have more access to capital market. Hence, stock insurers tend to undertake more risk than their mutual counterparts since they possess high level of risk tolerance. Therefore, we do not have prior expectations on how stock form affects market share.

Group

A dummy variable equals 1 if the insurer is affiliated and 0 if it is non-affiliated to a certain group. Insures affiliated with a group obtain the benefits from the reputation of the parent company. In addition, insurers could obtain funds and expertise provided by the parent company when needed. However, the parent company monitors the affiliated insurers. Therefore, we do not make prior expectations on how group is related to market share.

3.3 Regression models

Regression analysis is used to test our hypotheses regarding the effects of the tenure of insurer-reinsurer relationship on market share. The regression was set up as follows:

$$Market\_share_{i,t} = \beta_0 + \beta_1 \cdot Reins\_Sus_{i,t-1} + \beta_2 \cdot Reins\_Sus^2_{i,t-1} + \beta' \cdot CV_{i,t-1} + \varepsilon_{i,t} \quad (1)$$

$Market\_share_{i,t}$ indicates market share for firm i at time t. $Reins\_Sus_{i,t-1}$ denotes reinsurance sustainability for firm i at time t-1. $Reins\_Sus^2_{i,t-1}$ denotes the squared term of reinsurance sustainability for firm i at time t-1. $CV_{i,t-1}$ indicates control variables included in our analysis. $\varepsilon_{i,t}$ is a residual term for equation (1). β_1 and β_2 measures the effects of reinsurance sustainability on market share. β indicates the vector capturing the effects of control variables on insurer's market share.

We specify a lead-lagged relationship to avoid potential simultaneous causality

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problem (Andreou, Andreou, and Lambertides, 2021). Specifically, all independent variables are specified by 1-year lagging to alleviate the concerns regarding endogeneity (Géczy, Minton, and Schrand, 1997). Since we include lagged dependent variables as our independent variables, we must be aware of dynamic panel bias. Specifically, such bias is characterized by the association of lagged dependent variables and the errors. To solve the bias, autoregressive dynamic panel data models are used in estimating the estimators. Specifically, we use one step GMM-system and one step GMM-difference models to alleviate such bias. The former was developed by Blundell and Bond (1998) and the latter was developed Arellano and Bond (1991). In addition, we specify robust standard errors for one step GMM-system model and WC-robust for one step GMM-difference model (Wooldridge, 2016). Except for the dummy variables, all variables are intended to be winsorized at 1 percent level to mitigate the possible outlier problems (Lin et al., 2011).

4. Empirical results

4.1 Univariate analysis

Table 2 documents the summary statistics. Market share exhibits a mean of 2.25789 and a standard deviation of 4.95589. Average values of $Reins\_Sus\_total_{i,t-1}$, $Reins\_Sus\_p25_{i,t-1}$, $Reins\_Sus\_p50_{i,t-1}$ and $Reins\_Sus\_p75_{i,t-1}$ are 1.51289, 1.59468, 1.90456, and 2.25728, respectively. After screening all the summary statistics of each variable in this study, the statistics of all variables are seemed to be modest.

<Table 2 is inserted here>

To further test whether multicollinearity phenomenon exists, the values of variance inflation factor (VIF) for independent variables are computed. Except for reinsurance sustainability and its squared term, the VIF values for other independent variables are under 10, lower than the value of the rule of thumb cutoff of 10 (Kennedy, 1998). However, Studenmund (2001) denote that we do not have to solve multicollinearity problem if such multicollinearity problem does not make these empirical results insignificant. Based on the results, these results present that the coefficients of these four variables and its squared term are all significantly associated with market share. Therefore, we do not take measures to solve such problem.

Table 3 presents the Pearson correlation matrix, presenting simple correlation coefficients on the variable scrutinized in this essay. Reinsurance sustainability and the

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corresponding squared term are found to be positively correlated at 1 percent level with market share, except for the condition of $Reins\_Sus\_p75_{i,t-1}$, suggesting that reinsurance sustainability may be non-linearly correlated with market share. Reinsurance and the squared term of reinsurance are both positively associated with market share. These results also indicate that reinsurance is correlated with market share in a way of non-linearity. Firm size is found to be positively correlated with market share. The result provides the primary notion that larger firm have high reputation and spend more budget in advertising, resulting in higher market share. Financial leverage is positive associated with market share. The operating ratio is negatively correlated at 1 percent level with market share, providing primary results for supporting the notion that high operating expense results in lower market share due to higher insurance price. Loss ratio is found to be positively correlated at 1 percent level with market share, providing primary notion that lower insurance price induces higher insurance demand. Business diversification has a positive correlation at 1% significance with market share, providing primary support that they have the access to reach a larger number of potential customers. Geographical diversification has a positive correlation at 1% significance with market share, providing primary support that highly geographical diversified insurers tend to have more access to potential customers in various geographical area. Long-tail line is negatively associated with market share. Stock form is positively and significantly associated with market share. Group affiliation is found to be positive associated with market share, providing primary support that insurers could obtain funds and expertise provided by the parent company.

<Table 3 is inserted here>

4.2 Multivariate analysis

The results of the effects of reinsurance sustainability on market share by utilizing one-step GMM-system and one-step GMM-difference models and relevant tests are presented in Table 4, 5, 6, and 7. All evidences regarding the goodness of fit showing that all χ^2 values exhibit statistically significance, supporting the notion that the fitted model is more suitable than a null model without explanatory variables.

<Table 4, 5, 6, and 7 are inserted here>

One-step GMM-system and GMM-difference models are utilized in estimating such effects in Table 4, 5, 6, 7, 8, and 9. Lind and Mehlum (2010) develop and Haans, Pieters

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and He (2016) summarize a three-step procedure to examine whether complex inverted U-shaped relationship exist step by step. First, significant positive coefficients of reinsurance sustainability and significant negative coefficients of its squared term are shown in Table 4, 5, 6, and 7. Second, the slopes at the low end of reinsurance sustainability ranges from 0.087 to 0.74 and those values at high end ranges from -0.105 to -0.015. Both present significant, except for certain conditions. Third, the turning point of all the (inverted) U-shaped relationships ranges from 1.706 and 2.757, indicating that all points are located within the data range of reinsurance sustainability. According to the statistics of Sasabuchi-test, all of values of the statistic present significance at least 10% level, except for some condition of $Reins\_Sus\_p50_{i,t-1}$ and $Reins\_Sus\_p75_{i,t-1}$. Next, we estimate confidence intervals based on the Delta method. The confidence intervals for the Delta method in table 4, 5, 6, 7, and 8 denote that the four reinsurance sustainability values are within the limits of the data.

Combine all results mentioned above, overall, we conclude that reinsurance sustainability is complex inverted U-shape related to market share, consistent with our main hypothesis. The results indicate that insurers become more aggressive by lowering underwriting standard and insurance price to attract new customers and put less efforts in underwriting to maximize short-term performance and to take advantage over reinsurers since insurers possess high level private information and take advantage over current reinsurers by pretending their business as low-risk business since that reinsurers could not distinguish high-risk from low-risk at low level of reinsurance relationship. Thus, market share increases as the tenure of insurer-reinsurer relationship increases when the length of reinsurance relationship is short. On contrary, insurers with longer reinsurance relationship tend to underwrite conservatively since information asymmetry within reinsurance relationship is low. Specifically, low-risk insurers tend to retain with the current reinsurers and the current reinsurers tend to charge them with lower reinsurance premium. Thus, their opportunity cost of not being renewed increases with the increase of reinsurance relationship since the reduction of reinsurance premium increases as the reinsurance relationship increases. In figure 1, we follow Farah et al. (2021) and plot the tenure of insurer-reinsurer relationship-market share curve by maintaining other independent variable fixed at their respectively mean values and by using $Reins\_Sus\_total_{i,t-1}$. We find that market share increases when the tenure of insurer-reinsurer relationship is lower than 1.973, but lowers when such relation's

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duration is higher than 1.973.

<Figure 1 is inserted here>

Concerning control variables, consistent with our expectations, market share at time t-1 is positively associated with current market share at 1% significant level in all cases, indicating that insurers with higher market share in prior year tends to maintain higher market share in current period. Firm size is positively and significantly associated with market share in some cases, consistent with Chang (2019). The results suggest that larger insurers tend to exhibit higher market share since they have better reputation, higher underwriting capacity and spend more resources to advertise to attract many new customers. Financial leverage is negatively and significantly related with market share at 1% significant level in the cases of one-step GMM-system models, consistent with Chang (2019) and Zanjani (2002). The evidences provide the notion that highly levered insurers underwrite more conservatively and find it hard to attract new customers due to the solvency concerns. In addition, they are monitored by regulators and outsiders. Operating ratio is negative significant linked with market share in at the condition of one-step GMM-difference model, denoting that insurance price increases as operating expense increases, resulting in less insurance products purchased. The relationship between loss ratio and market share shows positive and significant, denoting that market share rises as the product price falls. The nexus between business diversification and market share shows negative and significant when using one-step GMM-system model, inconsistent with our expectations and Chang (2019). It may indicate that it is not beneficial for insurers to engage in multiple business lines. Geographical diversification is found to be positive associated with market share, providing evidences supporting the notion that insurers underwriting at different states tend to have higher market share since they have more access to customers. Commercial line ratio is negatively related with market share in some cases, consistent with empirical results of Chang (2019) and the notion that insurers underwriting high level of commercial lines tend to have lower market share since commercial line has a feature of high expense ratio (Regan, 1999). The nexus between long-tail line and market share exhibit negative and significant at convention level on the condition of one-step GMM-system and without year dummies, indicating that insurers underwriting high level of long-tail business expose to higher extent of uncertainty. Therefore, they underwrite more conservatively and hold high level of capital buffer to prevent the occurrence of adverse

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events. Stock form is positively and significantly related with market share, supporting the notion that stock form insurers have easy access to capital market and more risk tolerance and thus they are prone to undertake higher risk than mutual counterparts. The nexus between group and market share documents positive and significant evidence in some cases, meaning that insurers are benefited from their parent company in terms of the reputation and the necessary funds and expertise.

5. Reserve causality testing

Although we have tried to eliminate the concerns of reverse causality by specifying lead-lagged relationship in our main regression settings, it is expected that such concerns still exist. Specifically, four reinsurance sustainability variables in year t-1 are used to estimate market share of primary insurers in the subsequent year t in the previous analysis. Next, we follow Andreou et al. (2021) to swap the main variables of interest to emphasize whether dynamic reverse causality exists between reinsurance sustainability variables and market share. Specifically, this analysis is conducted by examining whether market share in year t-1 is associated with the four reinsurance sustainability measures in year t by using the one-step GMM-difference model.

<Table 8 is inserted here>

Table 8 presents the results of reverse causality testing. Except the condition when the dependent variable is $Reins\_sus\_total_{i,t}$, product diversification in year t-1 is not associated with $Reins\_sus\_total_{i,t}$ and $Reins\_sus\_p50_{i,t}$, respectively. Overall, the results denote that the past values of market share at time t-1 are not significantly correlated with reinsurance sustainability at time t. Specifically, our results provide support that the reinsurance sustainability-market share relationship does not exist dynamic reverse causality.

6. Conclusions

We set out in this study to determine whether the tenure of insurer-reinsurer relationship is related to market share, strategic performance, to advance the literature. In this study, we improve the measures of the tenure of insurer-reinsurer relationship by taking the amount of reinsurance premium in the reinsurance transaction into account to emphasize the importance of the insurer-reinsurer relationship. Using the NAIC data from 2013-2020 on a sample of US property-casualty insurance firms, we find that the

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tenure of insurer-reinsurer plays an important role in influencing market share of insurers. Specifically, we find that the tenure of insurer-reinsurer relationship is inverted U-shaped related with market share. Specifically, we observe that the effect of the tenure of insurer-reinsurer relationship on market share depend on the relation's duration levels. An increase in the tenure of insurer-reinsurer relationship results in significant gains in product-market share for insurers with shorter relation's duration at the expense of insurers with higher tenure.

Our findings have several important implications. For managers, they could take aggressive underwriting strategies when their relations with current reinsurers are low since their opportunity cost of not renewing reinsurance is low. In addition, it is not harmful for insurers to reduce market share due to put more efforts in underwriting since it may indicate they could purchase cheaper reinsurance in the future. Moreover, this study could enable policymakers to improve regulations focusing on long-term relationship basis. This study may provide supports for policy makers to generate some regulations to encourage insurers to maintain long-term relationship with incumbent reinsurers. Regarding reinsurance and information asymmetry literature, this study fills the research gap by providing evidences showing the non-linear (inverted U-shaped) effects of reinsurance contracting behaviors on strategic performance, market share.

Future research could focus how the long-term relationship in reinsurance market affects various dimension of insurers. Specifically, due to the data attainability, we could not obtain the value of the tenure of specific business line. However, we could investigate such effects on various business lines. In addition, we could investigate how the tenure of insurer-reinsurer relationship affects personal lines, commercial lines, short-tail lines, and long-tail lines, respectively, to give a whole picture of how relationship between insurer and reinsurer affects various dimensions of cedans.

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Table 1: Variable names and definitions

Variables	Definitions
Dependent variable	
$Market\_share_{i,t}$	The property casualty insurer's market share at time t. It is defined as the firm's direct premium written at time t to whole industry aggregate premium written at time t. (the values multiplied by 10,000)
Independent variable	
$Market\_share_{i,t-1}$	It is 1-year lagged market share.
$Reins\_Sus\_total_{i,t-1}$	A measure of reinsurance sustainability. It is defined as the ratio of the mean value of the reinsurance relationship count distribution divided by the standard deviation of the reinsurance relationship count distribution plus 1. In addition, this variable is calculated by including all reinsurance relationship transactions.
$Reins\_Sus\_total^2_{i,t-1}$	It is a squared term of reinsurance sustainability, $Reins\_Sus\_total_{i,t-1}$.
$Reins\_Sus\_p25_{i,t-1}$	A measure of reinsurance sustainability. It is defined as the ratio of the mean value of the reinsurance relationship count distribution divided by the standard deviation of the reinsurance relationship count distribution plus 1. In addition, this variable is calculated by including the reinsurance relationship transactions whose values are larger than the value of 25th percentile of all reinsurance relationships.
$Reins\_Sus\_p25^2_{i,t-1}$	It is a squared term of reinsurance sustainability, $Reins\_Sus\_p25_{i,t-1}$.
$Reins\_Sus\_p50_{i,t-1}$	A measure of reinsurance sustainability. It is defined as the ratio of the mean value of the reinsurance relationship count distribution divided by the standard deviation of the reinsurance relationship count distribution plus 1. In addition, this variable is calculated by including the reinsurance relationship transactions whose values are larger than the value of 50th percentile of all reinsurance relationships.
$Reins\_Sus\_p50^2_{i,t-1}$	It is a squared term of reinsurance sustainability, $Reins\_Sus\_p50_{i,t-1}$.
$Reins\_Sus\_p75_{i,t-1}$	A measure of reinsurance sustainability. It is defined as the ratio of the mean value of the reinsurance relationship count distribution divided by the standard deviation of the reinsurance relationship count distribution plus 1. In addition, this variable is calculated by including the reinsurance relationship transactions whose values are larger than the value of 75th percentile of all reinsurance relationships.
$Reins\_Sus\_p75^2_{i,t-1}$	It is a squared term of reinsurance sustainability, $Reins\_Sus\_p75_{i,t-1}$.
$Reins_{i,t-1}$	It is defined as the ratio of the amount of affiliated reinsurance ceded at time t-1 plus non-affiliated reinsurance ceded

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	at time t-1 divided by the amount of direct business written at time t-1 plus the amount of reinsurance assumed at time t-1.
$Reins^2_{i,t-1}$	It is the squared of the value of reinsurance mentioned above.
$Firm\_size_{i,t-1}$	It the value of natural logarithm of total net admitted assets at time t-1.
$Fin\_lev_{i,t-1}$	It is defined as the ratio of the amount of total liabilities at time t-1 divided by the amount of total net admitted assets at time t-1.
$Operate\_ratio_{i,t-1}$	It is the value of loss expense and underwriting expense at time t-1 divided by premium written at time t-1.
$Loss\_ratio_{i,t-1}$	It is defined as the value of the loss incurred and loss-adjusted expense at time t-1 divided by net premium written at time t-1.
$P\_diver_{i,t-1}$	It is derived from 1 minus the Herfindahl index by calculating the sum of the squares of the ratio of the dollar amount of direct business written in a particular line of insurance to the dollar amount of direct business across all 24 lines of insurance based on Berry-Stözle et al. (2012).
$G\_div_{i,t-1}$	It is defined as the sum of the squares of the ratio of the dollar amount of direct business in state j to the total amount of direct business across all states.
$Com\_line\ ratio_{i,t-1}$	The commercial lines of business ratio is defined as the sum of direct premium written of lines of (1) fire, (2) allied, (3) farm owners multiple peril, (4) commercial multiple peril, (5) mortgage guaranty, (6) ocean marine, (7) inland marine, (8) financial guaranty, (9) medical malpractice occurrence, (10) medical malpractice claims made, (11) earthquake, (12) group accident and health, (13) credit accident and health (group and individual), (14) other accident and health, (15) workers' compensation, (16) other liability occurrence, (17) other liability claims made, (18) products liability occurrence, (19) products liability claims made, (20) commercial auto liability, (21) aircraft (all perils), (22) fidelity, (23) surety, (24) burglary and theft, (25) boiler and machinery, and (26) credit at time t-1 divided by total amount of direct business written at time t-1.
$Long\_tail\ ratio_{i,t-1}$	The long-tail lines of business ratio is defined as the sum of net premium written of lines of (1) farm owners multiple peril, (2) homeowners multiple peril, (3) commercial multiple peril, (4) mortgage guaranty, (5) ocean marine, (6) medical malpractice occurrence, (7) medical malpractice claims made, (8) workers' compensation, (9) other liability occurrence, (10) other liability claims made, (11) product liability occurrence, (12) product liability claims made, (13) private passenger auto liability, (14) commercial auto liability, (15) aircraft (all perils), (16) boiler and machinery, (17) international, (18) warranty, (19) reinsurance-non-proportional assumed property, (20) reinsurance-nonproportional assumed liability, (21) reinsurance-non-proportional assumed financial lines, and (22) aggregate

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	write-ins for other lines of business divided by total amount of net premium written.
$Stock\_form_{i,t-1}$	Equals 1 if the insurer is a stock insurer, and 0 if the insurer is a mutual insurer.
$Group_{i,t-1}$	Equals 1 if the insurer is affiliated, and 0 if it is non-affiliated.

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Table 2: Descriptive analysis

Variables	Mean	S.D.	Min	25th	Median	75th	Max	N
Dependent variable								
$Market\_share_{i,t}$	2.20651	4.89096	0.00053	0.11996	0.53019	1.88457	42.65565	13,499
Independent variable								
$Market\_share_{i,t-1}$	2.25789	4.95589	0.00053	0.13098	0.55915	1.95542	42.65565	11,514
$Reins\_Sus\_total_{i,t-1}$	1.51289	1.13415	0.66555	0.92769	1.10798	1.41971	5.00000	11,514
$Reins\_Sus\_total^2_{i,t-1}$	3.57504	6.52545	0.44296	0.86060	1.22763	2.01560	25.00000	11,514
$Reins\_Sus\_p25_{i,t-1}$	1.59468	1.16190	0.66946	0.96281	1.16756	1.53961	5.00000	11,514
$Reins\_Sus\_p25^2_{i,t-1}$	3.89292	6.71969	0.44818	0.92701	1.36321	2.37041	25.00000	11,514
$Reins\_Sus\_p50_{i,t-1}$	1.90456	1.29127	0.69036	1.04555	1.38592	2.00000	5.00000	11,514
$Reins\_Sus\_p50^2_{i,t-1}$	5.29461	7.54181	0.47659	1.09318	1.92079	4.00000	25.00000	11,514
$Reins\_Sus\_p75_{i,t-1}$	2.25728	1.39046	0.73035	1.19782	1.68233	3.00000	5.00000	11,514
$Reins\_Sus\_p75^2_{i,t-1}$	7.02856	8.31076	0.53341	1.43478	2.83025	9.00000	25.00000	11,514
$Reins_{i,t-1}$	0.40135	0.28738	0.00000	0.14554	0.35900	0.63815	1.00000	11,514
$Reins^2_{i,t-1}$	0.24366	0.26874	0.00000	0.02118	0.12888	0.40723	1.00000	11,514
$Firm\_size_{i,t-1}$	18.62592	1.86040	13.71186	17.29803	18.57740	19.85062	23.29952	11,514
$Fin\_lev_{i,t-1}$	0.54078	0.17915	0.01609	0.43680	0.56898	0.67493	0.89832	11,514
$Operate\_ratio_{i,t-1}$	0.30458	0.28513	0.00662	0.15096	0.27586	0.38204	4.43736	11,514
$Loss\_ratio_{i,t-1}$	0.65738	0.26110	0.00000	0.54875	0.66993	0.75771	2.83922	11,514
$P\_diver_{i,t-1}$	0.37840	0.31185	0.00000	0.00495	0.43318	0.67320	0.85781	11,514

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$G\_div_{i,t-1}$	0.44108	0.39067	0.00000	0.00000	0.47571	0.85459	0.96429	11,514
$Com\_line\ ratio_{i,t-1}$	0.73359	0.28831	0.00000	0.54160	0.82126	1.00000	1.00000	11,514
$Long\_tail\ ratio_{i,t-1}$	0.74205	0.26678	0.00000	0.66418	0.79286	0.95375	1.00000	11,514
$Stock\_form_{i,t-1}$	0.73979	0.43876	0.00000	0.00000	1.00000	1.00000	1.00000	11,514
$Group_{i,t-1}$	0.68004	0.46648	0.00000	0.00000	1.00000	1.00000	1.00000	11,514

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Table 3: Pearson correlation matrix

Panel A

	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)
(a)	-										
(b)	0.991***	-									
(c)	0.066***	0.068***	-								
(d)	0.060***	0.062***	0.986***	-							
(e)	0.067***	0.069***	0.971***	0.949***	-						
(f)	0.064***	0.066***	0.962***	0.967***	0.985***	-					
(g)	0.049***	0.050***	0.815***	0.786***	0.843***	0.819***	-				
(h)	0.049***	0.050***	0.826***	0.817***	0.849***	0.849***	0.984***	-			
(i)	0.013	0.014	0.685***	0.651***	0.713***	0.682***	0.850***	0.824***	-		
(j)	0.011	0.012	0.702***	0.682***	0.728***	0.713***	0.851***	0.848***	0.984***	-	
(k)	0.088***	0.086***	0.134***	0.141***	0.131***	0.139***	0.111***	0.122***	0.072***	0.085***	-
(l)	0.103***	0.101***	0.147***	0.154***	0.141***	0.150***	0.117***	0.129***	0.081***	0.095***	0.963***
(m)	0.598***	0.599***	-0.023***	-0.031***	-0.020**	-0.027***	-0.052***	-0.056***	-0.079***	-0.088***	-0.051***
(n)	0.185***	0.186***	0.011	0.010	0.006	0.007	-0.016*	-0.011	-0.049***	-0.047***	0.069***
(o)	-0.152***	-0.150***	-0.087***	-0.089***	-0.091***	-0.092***	-0.084***	-0.087***	-0.066***	-0.070***	-0.440***
(p)	0.082***	0.081***	-0.012	-0.009	-0.009	-0.005	-0.019	-0.013	-0.044***	-0.041***	0.102***
(q)	0.196***	0.199***	-0.012	-0.004	-0.014	-0.009	-0.031***	-0.033***	-0.054***	-0.060***	0.165***
(r)	0.326***	0.322***	0.013	0.007	0.004	-0.001	-0.029***	-0.032***	-0.057***	-0.062***	0.176***
(s)	-0.015	-0.015	-0.021	-0.034***	-0.036***	-0.044***	-0.049***	-0.053***	-0.039***	-0.041***	-0.052***
(t)	-0.025***	-0.024**	-0.036***	-0.036***	-0.037***	-0.037***	-0.044***	-0.046***	-0.048***	-0.049***	-0.016*

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(u)	0.091***	0.087***	0.060***	0.066***	0.049***	0.057***	0.023***	0.037***	0.003	0.019***	0.230***
(v)	0.237***	0.236***	0.027***	0.029***	0.024***	0.027***	-0.006	-0.004	-0.030***	-0.032***	0.267***

Panel B	(l)	(m)	(n)	(o)	(p)	(q)	(r)	(s)	(t)	(u)	(v)
(l)	-										
(m)	-0.049***	-									
(n)	0.042***	0.349***	-								
(o)	-0.410***	-0.135***	-0.220***	-							
(p)	0.120***	0.123***	0.233***	0.038***	-						
(q)	0.123***	0.258***	0.085***	-0.200***	-0.015	-					
(r)	0.178***	0.488***	0.190***	-0.121***	0.027***	0.233***	-				
(s)	-0.030***	0.088***	0.064***	0.108***	-0.015	-0.152***	0.257***	-			
(t)	-0.023**	0.083***	0.188***	-0.090***	0.142***	0.016*	-0.062***	-0.037***	-		
(u)	0.230***	0.149***	0.230***	-0.134***	0.027***	-0.063***	0.271***	0.032***	-0.059***	-	
(v)	0.262***	0.443***	0.169***	-0.197***	0.102***	0.228***	0.343***	-0.038***	-0.036***	0.307***	-

Note: 1. (a) $Market\_share_{i,t}$, (b) $Market\_share_{i,t-1}$, (c) $Reins\_Sus\_total_{i,t-1}$, (d) $Reins\_Sus\_total^2_{i,t-1}$, (e) $Reins\_Sus\_p25_{i,t-1}$, (f) $Reins\_Sus\_p25^2_{i,t-1}$, (g) $Reins\_Sus\_p50_{i,t-1}$, (h) $Reins\_Sus\_p50^2_{i,t-1}$ (i) $Reins\_Sus\_p75_{i,t-1}$, (j) $Reins\_Sus\_p75^2_{i,t-1}$, (k) $Reins_{i,t-1}$, (l) $Reins^2_{i,t-1}$, (m) $Firm\_size_{i,t-1}$, (n) $Fin\_lev_{i,t-1}$, (o) $Operate\_ratio_{i,t-1}$, (p) $Loss\_ratio_{i,t-1}$, (q) $P\_diver_{i,t-1}$, (r) $G\_div_{i,t-1}$, (s) $Com\_line\ ratio_{i,t-1}$, (t) $Long\_tail\ ratio_{i,t-1}$ (u) $Stock\_form_{i,t-1}$, and (v) $Group_{i,t-1}$.
2. *, **, *** indicates significant level of 0.01, 0.05 and 0.1, respectively.

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Table 4: The effects of the tenure of insurer-reinsurer relationship ($Reins\_Sus\_total$) on market share.

	Dependent variable: $Market\_share_{i,t}$							
Models	one-step GMM-system				one-step GMM-difference			
Variables	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
Constant	-8.55605***	2.24506	-19.98586***	3.73208	2.75204	2.23566	-4.11671***	1.11434
$Market\_share_{i,t-1}$	0.81771***	0.01644	0.74112***	0.02733	0.37532***	0.04787	0.36111***	0.04949
$Reins\_Sus\_total_{i,t-1}$	0.13799**	0.05566	0.08551*	0.05113	0.12971***	0.04262	0.08543**	0.03938
$Reins\_Sus\_total^2_{i,t-1}$	-0.03496***	0.01081	-0.01942**	0.00906	-0.02901***	0.00832	-0.01815***	0.00709
$Reins_{i,t-1}$	-0.43524	0.34569	-0.43320	0.35263	-0.20607	0.24420	-0.27472	0.24913
$Reins^2_{i,t-1}$	0.31934	0.35606	0.57821	0.37927	0.02406	0.23384	0.23175	0.24061
$Firm\_size_{i,t-1}$	0.44995***	0.11996	1.11219	0.20430	-0.06586	0.12633	0.32045***	0.06265
$Fin\_lev_{i,t-1}$	-0.62543***	0.23099	-1.04453***	0.26668	0.10625	0.16215	-0.19867*	0.11534
$Operate\_ratio_{i,t-1}$	-0.00712	0.04709	0.06657	0.05454	-0.13000**	0.05797	-0.08597**	0.03753
$Loss\_ratio_{i,t-1}$	0.18888**	0.07749	0.08053	0.06586	0.15772***	0.04693	0.06440*	0.03659
$P\_diver_{i,t-1}$	-1.27076***	0.33448	-1.18509	0.38982	0.04984	0.10983	0.04743	0.12919
$G\_div_{i,t-1}$	2.18401***	0.37589	2.13382	0.40260	0.25839*	0.13704	0.33844**	0.16862
$Com\_line\ ratio_{i,t-1}$	-0.81370**	0.37405	-1.12104	0.39938	-0.20777	0.20680	-0.29524	0.19777
$Long\_tail\ ratio_{i,t-1}$	-0.48496**	0.23674	-0.39801	0.25685	-0.02764	0.12424	-0.04061	0.12635
$Stock\_form_{i,t-1}$	1.69986***	0.39705	1.68939	0.41478	-0.18302	0.26022	-0.14371	0.25932
$Group_{i,t-1}$	0.08082*	0.04152	0.21233	0.06141	-0.02532	0.01593	0.07414*	0.03905
Year dummies	No		Yes		No		Yes	

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Obs	11,161	11,161	9,300	9,300
Number of firms	1,689	1,689	1,543	1,543
AR(1)	-2.430 **(0.015)	-1.951 *(0.051)	1.937 *(0.052)	1.947 *(0.051)
λ^2 (p-value)	13018.350***(0.000)	9933.200***(0.000)	150.170***(0.000)	211.940***(0.000)
U-shaped testing				
Sasabuchi-test (p-value)	0.003***	0.036**	0.000***	0.011**
Estimated extreme point	1.973	2.202	2.235	2.353
Slope (Lower bound)	0.197***	0.118**	0.178***	0.116**
Slope (Upper bound)	-0.105***	-0.049***	-0.072***	-0.041***
95% (C.I.) -Delta method	(1.495, 2.451)	(1.466, 2.937)	(1.897, 2.573)	(1.880, 2.826)

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Table 5: The effects of the tenure of insurer-reinsurer relationship ($Reins\_Sus\_p25$) on market share.

	Dependent variable: $Market\_share_{i,t}$							
Models	one-step GMM-system				one-step GMM-difference			
Variables	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
$Constant$	-8.57749***	2.24656	-19.99547***	3.73232	2.72578	2.22886	-4.10785***	1.11287
$Market\_share_{i,t-1}$	0.81757***	0.01645	0.74106***	0.02731	0.37486***	0.04789	0.36095***	0.04947
$Reins\_Sus\_p25_{i,t-1}$	0.08912*	0.04781	0.06115	0.04530	0.12074***	0.03860	0.08944**	0.03654
$Reins\_Sus\_p25^2_{i,t-1}$	-0.02611***	0.00951	-0.01416*	0.00806	-0.02806***	0.00780	-0.01900***	0.00665
$Reins_{i,t-1}$	-0.42920	0.34500	-0.43038	0.35231	-0.20411	0.24380	-0.27345	0.24879
$Reins^2_{i,t-1}$	0.31326	0.35535	0.57560	0.37894	0.02308	0.23362	0.23087	0.24033
$Firm\_size_{i,t-1}$	0.45072***	0.12001	1.11243***	0.20430	-0.06448	0.12597	0.31993***	0.06257
$Fin\_lev_{i,t-1}$	-0.62227***	0.23078	-1.04304***	0.26645	0.10812	0.16237	-0.19666*	0.11547
$Operate\_ratio_{i,t-1}$	-0.00563	0.04711	0.06717	0.05461	-0.12925**	0.05780	-0.08589**	0.03759
$Loss\_ratio_{i,t-1}$	0.19126**	0.07768	0.08090	0.06591	0.15862***	0.04703	0.06465*	0.03661
$P\_diver_{i,t-1}$	-1.27723***	0.33492	-1.18737***	0.39010	0.04437	0.10974	0.04460	0.12920
$G\_div_{i,t-1}$	2.19029***	0.37671	2.13660***	0.40277	0.25895*	0.13722	0.33737**	0.16841
$Com\_line\ ratio_{i,t-1}$	-0.81258**	0.37431	-1.11867***	0.39951	-0.20459	0.20689	-0.29325	0.19774
$Long\_tail\ ratio_{i,t-1}$	-0.48608**	0.23660	-0.39780	0.25673	-0.02820	0.12418	-0.04096	0.12624
$Stock\_form_{i,t-1}$	1.70474***	0.39763	1.69268***	0.41507	-0.18278	0.26024	-0.14376	0.25930
$Group_{i,t-1}$	0.08066*	0.04155	0.21254***	0.06142	-0.02607	0.01593	0.07344*	0.03896
Year dummies	No		Yes		No		Yes	

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Obs	11,161	11,161	9,300	9,300
Number of firms	1,689	1,689	1,543	1,543
AR(1)	-2.439 **(0.0147)	-1.953 *(0.050)	1.9335 *(0.053)	1.9442 *(0.051)
λ^2 (p-value)	12984.430***(0.000)	9958.010***(0.000)	153.600***(0.000)	212.760***(0.000)
U-shaped testing				
Sasabuchi-test (p-value)	0.017**	0.072*	0.000***	0.005***
Estimated extreme point	1.706	2.159	2.151	2.353
Slope (Lower bound)	0.137**	0.087*	0.172***	0.124***
Slope (Upper bound)	-0.088**	-0.035***	-0.070***	-0.039***
95% (C.I.) -Delta method	(1.019, 2.394)	(1.227, 3.091)	(1.817, 2.484)	(1.945, 2.761)

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Table 6: The effects of the tenure of insurer-reinsurer relationship ($Reins\_Sus\_p50$) on market share.

	Dependent variable: $Market\_share_{i,t}$							
Models	one-step GMM-system				one-step GMM-difference			
Variables	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
$Constant$	-8.58108***	2.25347	-20.00659***	3.73288	2.75772	2.22942	-4.07194***	1.10971
$Market\_share_{i,t-1}$	0.81710***	0.01655	0.74089***	0.02731	0.37394***	0.04797	0.36060***	0.04947
$Reins\_Sus\_p50_{i,t-1}$	0.09367**	0.04276	0.05994	0.03818	0.16519***	0.04041	0.12284***	0.03494
$Reins\_Sus\_p50^2_{i,t-1}$	-0.02612***	0.00887	-0.01133*	0.00672	-0.03498***	0.00820	-0.02228***	0.00599
$Reins_{i,t-1}$	-0.44320	0.34550	-0.43065	0.35311	-0.21271	0.24410	-0.27118	0.24873
$Reins^2_{i,t-1}$	0.33469	0.35592	0.57704	0.38002	0.03728	0.23329	0.23020	0.24050
$Firm\_size_{i,t-1}$	0.45167***	0.12057	1.11294***	0.20434	-0.06547	0.12590	0.31820***	0.06238
$Fin\_lev_{i,t-1}$	-0.62104***	0.23055	-1.04557***	0.26616	0.10326	0.16237	-0.20143*	0.11539
$Operate\_ratio_{i,t-1}$	-0.00481	0.04707	0.06662	0.05468	-0.13050**	0.05823	-0.08768**	0.03792
$Loss\_ratio_{i,t-1}$	0.18994**	0.07772	0.08043	0.06626	0.15618***	0.04678	0.06393*	0.03681
$P\_diver_{i,t-1}$	-1.28287***	0.33459	-1.18249***	0.39038	0.04762	0.11037	0.05286	0.12981
$G\_div_{i,t-1}$	2.19781***	0.37712	2.13743***	0.40258	0.26147*	0.13775	0.33571**	0.16839
$Com\_line\ ratio_{i,t-1}$	-0.83982**	0.37286	-1.11889***	0.39834	-0.22149	0.20564	-0.29823	0.19793
$Long\_tail\ ratio_{i,t-1}$	-0.50050**	0.23385	-0.40102	0.25568	-0.04059	0.12350	-0.04865	0.12579
$Stock\_form_{i,t-1}$	1.72511***	0.39760	1.70028***	0.41473	-0.16694	0.25945	-0.13377	0.25890
$Group_{i,t-1}$	0.08268**	0.04177	0.21362***	0.06154	-0.02483	0.01627	0.07455*	0.03916
Year dummies	No		Yes		No		Yes	

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Obs	11,161	11,161	9,300	9,300
Number of firms	1,689	1,689	1,543	1,543
AR(1)	-2.4215 *(0.015)	-1.943 *(0.052)	1.941 *(0.052)	1.9484 *(0.051)
λ^2 (p-value)	12838.060***(0.000)	10037.950***(0.000)	165.430***(0.000)	212.470***(0.000)
U-shaped testing				
Sasabuchi-test (p-value)	0.000***	0.155	0.000***	0.003***
Estimated extreme point	1.792	2.645	2.361	2.757
Slope (Lower bound)	0.157***	0.087*	0.250***	0.176***
Slope (Upper bound)	-0.068***	-0.010	-0.051***	-0.015***
95% (C.I.) -Delta method	(1.250, 2.335)	(1.855, 3.436)	(2.148, 2.574)	(2.528, 2.985)

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Table 7: The effects of the tenure of insurer-reinsurer relationship ($Reins\_Sus\_p75$) on market share.

	Dependent variable: $Market\_share_{i,t}$							
Models	one-step GMM-system				one-step GMM-difference			
Variables	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
Constant	-8.59334***	2.25517	-20.00509***	3.73304	2.75533	2.22789	-10.53181***	3.86303
$Market\_share_{i,t-1}$	0.81710***	0.01655	0.74089***	0.02731	0.37394***	0.04797	0.80804***	0.03529
$Reins\_Sus\_p75_{i,t-1}$	0.09367**	0.04276	0.05994	0.03818	0.16519***	0.04041	0.01752	0.02571
$Reins\_Sus\_p75^2_{i,t-1}$	-0.02612***	0.00887	-0.01133*	0.00672	-0.03498***	0.00820	-0.00171	0.00425
$Reins_{i,t-1}$	-0.44320	0.34550	-0.43065	0.35311	-0.21271	0.24410	0.11098	0.34317
$Reins^2_{i,t-1}$	0.33469	0.35592	0.57704	0.38002	0.03728	0.23329	-0.36407	0.40099
$Firm\_size_{i,t-1}$	0.45167***	0.12057	1.11294***	0.20434	-0.06547	0.12590	0.57126***	0.21636
$Fin\_lev_{i,t-1}$	-0.62104***	0.23055	-1.04557***	0.26616	0.10326	0.16237	-0.33281*	0.19834
$Operate\_ratio_{i,t-1}$	-0.00481	0.04707	0.06662	0.05468	-0.13050**	0.05823	-0.07568	0.05391
$Loss\_ratio_{i,t-1}$	0.18994**	0.07772	0.08043	0.06626	0.15618***	0.04678	-0.09594	0.08156
$P\_diver_{i,t-1}$	-1.28287***	0.33459	-1.18249***	0.39038	0.04762	0.11037	0.27116	0.38813
$G\_div_{i,t-1}$	2.19781***	0.37712	2.13743***	0.40258	0.26147*	0.13775	1.43425***	0.47854
$Com\_line\ ratio_{i,t-1}$	-0.83982**	0.37286	-1.11889***	0.39834	-0.22149	0.20564	-0.12984	0.25497
$Long\_tail\ ratio_{i,t-1}$	-0.50050**	0.23385	-0.40102	0.25568	-0.04059	0.12350	-0.41362*	0.25084
$Stock\_form_{i,t-1}$	1.72511***	0.39760	1.70028***	0.41473	-0.16694	0.25945	0.73131	0.49979
$Group_{i,t-1}$	0.08268**	0.04177	0.21362***	0.06154	-0.02483	0.01627	-0.02873	0.04780
Year dummies	No		Yes		No		Yes	

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Obs	11,161	11,161	9,300	9,300
Number of firms	1,689	1,689	1,543	1,543
AR(1)	-2.4215 **(0.015)	-1.9433 *(0.052)	1.9412 *(0.052)	-2.4185 **(0.015)
λ^2 (p-value)	12838.060***(0.000)	10037.950***(0.000)	165.430***(0.000)	4106.900***(0.000)
U-shaped testing				
Sasabuchi-test (p-value)	0.006***	0.403	0.001***	N/A
Estimated extreme point	1.792	2.645	2.361	2.757
Slope (Lower bound)	0.175***	0.095*	0.274***	0.192
Slope (Upper bound)	-0.049***	-0.002	-0.026***	0.000
95% (C.I.) -Delta method	(1.250, 2.335)	(1.855, 3.436)	(2.148, 2.574)	(2.528, 2.985)

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Table 8: Reverse causality testing

Dependent variable:	$Reins\_Sus\_total_{i,t}$		$Reins\_Sus\_p50_{i,t}$	
Model	one-step GMM-difference			
Variables	Coefficient	S.D.	Coefficient	S.D.
$Market\_share_{i,t-1}$	-0.00003	0.00883	-0.00174	0.01113
Control variables	Yes		Yes	
Year dummies	Yes		Yes	
N	9,300		9,300	
Firms	1,543		1,543	
λ^2 value (p value)	154.48		228.70	

Note: ***, **, * represent statistical significance at 0.01, 0.05, and 0.1 levels, respectively.

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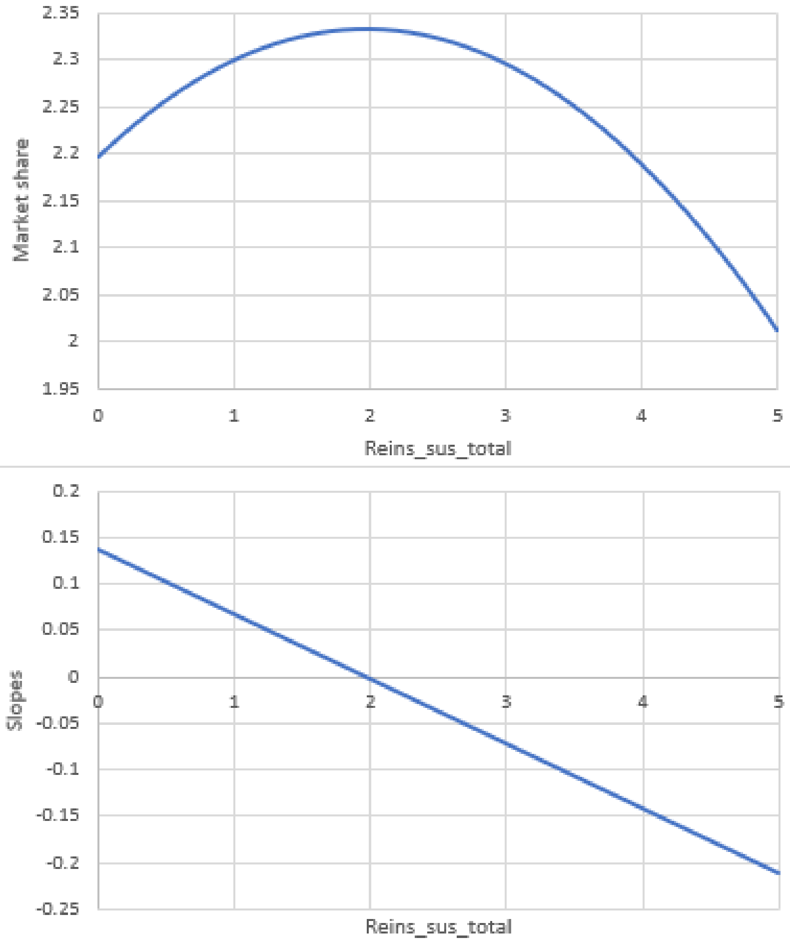
Figure 1: The effects of reinsurance sustainability ($Reins\_Sus\_total$) on market share.



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Appendix

In this appendix, we will consider two situations for our numerical analysis. The main purpose of this numerical analysis is to lead readers to understand how reinsurance sustainability measures, $Reins\_Sus\_total$, $Reins\_Sus\_p25$, $Reins\_Sus\_p50$, and $Reins\_Sus\_p75$ are constructed and calculated, respectively.

Next, we consider two reinsurance relationship conditions. In the following examples, we first calculate the specified percentile statistics, choose the reinsurance relationship, and then calculate the values of the four reinsurance sustainability measures step by step.

Example 1:

Table 1: 5-year rolling window for example 1.

Reinsurers	Year 1	Year 2	Year 3	Year 4	Year 5	Counts	Amount
(1)	3000	3100	3200	3300	3400	5	16000
(2)	2900	3000	3100	3200	3300	5	15500
(3)	2500	2600	2700	2800	2900	5	13500
(4)	2200	2300	2400	2500	2600	5	12000
(5)	2000	2100	2200	2300	2400	5	11000
(6)	500	550	600	650	700	5	3000
(7)	450	460	470	480	490	5	2350
(8)	350	360	370	380	390	5	1850
(9)	300	320	340	360	380	5	1700
(10)	100	110	120	130	140	5	600

Where *Reinsurers* indicate the ith reinsurer, $i = 1, 2, \ldots, 10$. The column indicating Year 1 to Year 5 documents the amount of reinsurance premium ceded for each condition. For example, for reinsurer (1) in Year 1, the amount of reinsurance premium ceded is 3000. Counts denotes the years that the cedant purchasing reinsurance with the incumbent reinsurer over the past 5 years. Amount also indicates the amount of reinsurance premium ceded that the cedant purchasing reinsurance with the current reinsurer over the past 5 years.

In the first example, we calculate the values of various reinsurance sustainability by the following steps:

First, we calculate the values of every specified percentile of the *Amounts*, including the 25^{th}, 50^{th}, 75^{th} percentile of the *Amount* to capture different levels of important reinsurance relationships.

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The 25th percentile of the *Amount*: $P_{25} = 1{,}975$.

The 50th percentile of the *Amount*: $P_{50} = 7{,}000$.

The 75th percentile of the *Amount*: $P_{75} = 13{,}125$.

Second, we calculate every reinsurance sustainability measure discussed in the main text:

[1] $Reins\_Sus\_total$

$$\mu_{1,Total} = \frac{1}{10}\sum_{i=1}^{10} Counts_{i,1} = \frac{1}{10}(5+5+5+5+5+5+5+5+5+5) = 5$$

$$\sigma_{1,Total} = \sqrt{\frac{1}{10}\sum_{i=1}^{10}\left(Counts_{i,1} - \mu_{1,Total}\right)^2}$$

$$= \sqrt{\frac{1}{10}(0^2+0^2+0^2+0^2+0^2+0^2+0^2+0^2+0^2+0^2)} = 0$$

Thus, $Reins\_Sus\_total = \frac{\mu_{1,Total}}{\sigma_{1,Total}+1} = \frac{5}{(0+1)} = 5$

Specifically, we include all reinsurance relationship from (1) to (10) into calculating the value of $Reins\_Sus\_total$.

[2] $Reins\_Sus\_p25$

$$\mu_{1,p25} = \frac{1}{7}\sum_{i=1}^{7} Counts_{i,1} = \frac{1}{7}(5+5+5+5+5+5+5) = 5$$

$$\sigma_{1,p25} = \sqrt{\frac{1}{7}\sum_{i=1}^{7}\left(Counts_{i,1} - \mu_{1,p25}\right)^2}$$

$$= \sqrt{\frac{1}{7}(0^2+0^2+0^2+0^2+0^2+0^2+0^2)} = 0$$

Thus, $Reins\_Sus\_p25 = \frac{\mu_{1,p25}}{\sigma_{1,p25}+1} = \frac{5}{(0+1)} = 5$

Specifically, we exclude the reinsurance relationships numbered from (8) to (10) and include reinsurance relationships numbered from (1) to (7) into calculating the value of $Reins\_Sus\_p25$ since the 25th percentile of the *Amount* is $1{,}975$.

[3] $Reins\_Sus\_p50$

$$\mu_{1,p50} = \frac{1}{5}\sum_{i=1}^{5} Counts_{i,1} = \frac{1}{5}(5+5+5+5+5) = 5$$

$$\sigma_{1,p50} = \sqrt{\frac{1}{5}\sum_{i=1}^{5}\left(Counts_{i,1} - \mu_{1,p50}\right)^2}$$

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$$= \sqrt{\frac{1}{5}(0^2 + 0^2 + 0^2 + 0^2 + 0^2)} = 0$$

Thus, $Reins\_Sus\_p50 = \frac{\mu_{1,p50}}{\sigma_{1,p50}+1} = \frac{5}{(0+1)} = 5$

Specifically, we exclude the reinsurance relationships numbered from (6) to (10) and include reinsurance relationships numbered from (1) to (5) into calculating the value of $Reins\_Sus\_p50$ since the 50th percentile of the *Amount* is $7{,}000$.

[4] $Reins\_Sus\_p75$

$$\mu_{1,p75} = \frac{1}{3}\sum_{i=1}^{3} Counts_{i,1} = \frac{1}{3}(5 + 5 + 5)$$

$$= 5$$

$$\sigma_{1,p75} = \sqrt{\frac{1}{3}\sum_{i=1}^{3}\left(Counts_{i,1} - \mu_{1,p75}\right)^2}$$

$$= \sqrt{\frac{1}{3}(0^2 + 0^2 + 0^2)} = 0$$

Thus, $Reins\_Sus\_p75 = \frac{\mu_{1,p75}}{\sigma_{1,p75}+1} = \frac{5}{(0+1)} = 5$

Specifically, we exclude the reinsurance relationships numbered from (4) to (10) and include reinsurance relationships numbered from (1) to (3) into calculating the value of $Reins\_Sus\_p75$ since the 75th percentile of the *Amount* is $13{,}125$.

Table 2: Summary of example 1

	$Reins\_Sus\_total$	$Reins\_Sus\_p25$	$Reins\_Sus\_p50$	$Reins\_Sus\_p75$
Values	5	5	5	5

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Example 2:

Table 3: 5-year rolling window for example 2.

Reinsurers	Year 1	Year 2	Year 3	Year 4	Year 5	Counts	Amount
(1)	3000	3100	3200	3300	3400	5	16000
(2)	2900	3000	3100	3200	3300	5	15500
(3)			2400	2500	2600	3	7500
(4)	2500	2600				2	5100
(5)			600	650	700	3	1950
(6)	500	550				2	1050
(7)		460	470			2	930
(8)					390	1	390
(9)				360		1	360
(10)	100					1	100

In the second example, we calculate the values of various reinsurance sustainability by the following steps:

First, we calculate the values of every specified percentile of the *Amounts*, including the 25th, 50th, 75th percentile of the *Amount* to capture different levels of important reinsurance relationships.

The 25th percentile of the *Amount*: $P_{25} = 525$.

The 50th percentile of the *Amount*: $P_{50} = 1{,}500$.

The 75th percentile of the *Amount*: $P_{75} = 6{,}900$.

Second, we calculate every reinsurance sustainability measure discussed in the main text:

[1] $Reins\_Sus\_total$

$$\mu_{2,Total} = \frac{1}{10}\sum_{i=1}^{10} Counts_{i,2} = \frac{1}{10}(5+5+3+2+3+2+2+1+1+1)$$

$$= 2.5$$

$$\sigma_{2,Total} = \sqrt{\frac{1}{10}\sum_{i=1}^{10}\left(Counts_{i,2} - \mu_{2,Total}\right)^2}$$

$$= \sqrt{\frac{1}{10}(5-2.5)^2 + \frac{1}{10}(5-2.5)^2 + \frac{1}{10}(3-2.5)^2 + \cdots + \frac{1}{10}(1-2.5)^2}$$

$$= 1.509$$

Thus, $Reins\_Sus\_total = \frac{\mu_{2,Total}}{\sigma_{2,Total}+1} = \frac{2.5}{(1.509+1)} = 0.996$

Specifically, we include all reinsurance relationship from (1) to (10) into calculating the value of $Reins\_Sus\_total$.

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[2] $Reins\_Sus\_p25$

$$\mu_{2,p25} = \frac{1}{7}\sum_{i=1}^{7} Counts_{i,2} = \frac{1}{7}(5+5+3+2+3+2+2)$$
$$= 3.143$$
$$\sigma_{2,p25} = \sqrt{\frac{1}{7}\sum_{i=1}^{7}\left(Counts_{i,2} - \mu_{2,p25}\right)^2}$$
$$= \sqrt{\frac{1}{7}(5-3.143)^2 + \frac{1}{7}(5-3.143)^2 + \frac{1}{7}(3-3.143)^2 + \cdots + \frac{1}{7}(2-3.143)^2}$$
$$= 1.345$$

Thus, $Reins\_Sus\_p25 = \frac{\mu_{1,p25}}{\sigma_{1,p25}+1} = \frac{3.143}{(1.345+1)} = 1.340$

Specifically, we exclude the reinsurance relationships numbered from (8) to (10) and include reinsurance relationships numbered from (1) to (7) into calculating the value of $Reins\_Sus\_p25$ since the 25th percentile of the *Amount* is 525.

[3] $Reins\_Sus\_p50$

$$\mu_{2,p50} = \frac{1}{5}\sum_{i=1}^{5} Counts_{i,2} = \frac{1}{5}(5+5+3+2+3)$$
$$= 3.6$$
$$\sigma_{2,p50} = \sqrt{\frac{1}{5}\sum_{i=1}^{5}\left(Counts_{i,2} - \mu_{2,p50}\right)^2}$$
$$= \sqrt{\frac{1}{5}(5-3.6)^2 + \frac{1}{5}(5-3.6)^2 + \frac{1}{5}(3-3.6)^2 + \cdots + \frac{1}{5}(3-3.6)^2}$$
$$= 1.341$$

Thus, $Reins\_Sus\_p50 = \frac{\mu_{1,p50}}{\sigma_{1,p50}+1} = \frac{3.6}{(1.341+1)} = 1.537$

Specifically, we exclude the reinsurance relationships numbered from (6) to (10) and include reinsurance relationships numbered from (1) to (5) into calculating the value of $Reins\_Sus\_p50$ since the 50th percentile of the *Amount* is 1,500.

[4] $Reins\_Sus\_p75$

$$\mu_{2,p75} = \frac{1}{3}\sum_{i=1}^{3} Counts_{i,2} = \frac{1}{3}(5+5+3)$$
$$= 4.333$$
$$\sigma_{2,p75} = \sqrt{\frac{1}{3}\sum_{i=1}^{3}\left(Counts_{i,2} - \mu_{2,p75}\right)^2}$$
$$= \sqrt{\frac{1}{3}(5-4.333)^2 + \frac{1}{3}(5-4.333)^2 + \frac{1}{5}(3-4.333)^2} = 0.942$$

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Thus, $Reins\_Sus\_p75 = \frac{\mu_{1,p75}}{\sigma_{1,p75}+1} = \frac{4.333}{(0.942+1)} = 2.230$

Specifically, we exclude the reinsurance relationships numbered from (4) to (10) and include reinsurance relationships numbered from (1) to (3) into calculating the value of $Reins\_Sus\_p75$ since the 75th percentile of the *Amount* is $6{,}900$.

Table 4: Summary of example 2

	$Reins\_Sus\_total$	$Reins\_Sus\_p25$	$Reins\_Sus\_p50$	$Reins\_Sus\_p75$
Values	0.996	1.340	1.537	2.230

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