The New Generation of Capital Requirements in the Insurance Industry:

A Comparative Analysis of RBC Standards, Solvency II, and C-ROSS

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Abstract

RBC standards, Solvency II, and C-ROSS are three risk based solvency systems effective in the largest three insurance markets worldwide that are the U.S., European Union, and China. We qualitatively and quantitatively compare the solvency capital requirement (SCR) of the three solvency systems for three stylized assets and insurance portfolios capturing asset, liability, and insurance portfolio structure in the three markets, respectively. Our numerical results show that standard formula of Solvency II yields higher SCRs than RBC and C-ROSS for representative insurers with the same asset size based in all three markets. Moreover, we present rationales and document empirical evidence for one possible explanation of inconsistencies among solvency systems, that is the regulation's adaptation to the portfolio structure in respective markets. We thus conclude that the global standard, if desired, should start among countries with similar market portfolio structure and should be flexible enough to allow for market oriented adaptations.

Keywords

Insurance regulation, solvency, capital requirement, risk-based capital

JEL code: G22, G28

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1. Introduction

An important theme in recent discussion of financial regulation is the globally consistent capital standard, where similar rules and capital requirements are applied to similar activities. Both advantages and disadvantages of the global consistency exist in terms of capital standard. On the one hand, the consistent regulation decreases the costs of global operation for multinational firms, improving the global welfare (Flamée and Windels, 2009). Moreover, the consistency of capital requirement minimizes the risk of regulatory arbitrage (Bomhard, 2010) and promotes efficient allocation of economic recourses (Houston, Lin, and Ma, 2012). The consistency is also the goal for many regulatory authorities, including U.S. and EU (Siegel, 2013; IAIS, 2014). However, some studies also show that the consistent regulation increases social welfare only when the difference in regulator abilities between economies is not too large (Morrison and White, 2009) and when the market exit mechanisms are also global consistent (Acharya, 2003).

Although the global consistent regulation is the goal for regulatory authorities, unlike in the banking industry, where Basel III standards coordinate the national regulations (Laas and Siegel, 2016), the insurance regulatory systems in respective markets remain independent (Holzmueller, 2009), may yielding different capital standard (Holzmueller, 2009). Three independent solvency systems are implemented in three major markets that are U.S., European Union (EU), and mainland China. In the U.S., Risk-Based Capital (RBC) system was introduced in early 1990s and modernized in 2013 via Solvency Modernization Initiative (SMI). In the EU and mainland China, Solvency II and C-ROSS (China Risk Oriented Solvency System) are enforced in January 2016 as their second generation of solvency regulatory systems, respectively. In 2016, the three regulatory systems cover around 60% worldwide insurance premium (IAIS, 2017). The quantitative requirement is one of the most important part of the three regulatory systems. As the quantitative requirement, all of the three regulatory systems set a solvency capital requirement (SCR) for insurers operating in their jurisdictions, which are calculated based on each insurer’s risks including market, credit, underwriting, and possibly operational risk.

Motivated by the discussion of global consistency and the authorities' goal, this article empirically investigates whether the RBC, Solvency II, and C-ROSS are consistent in terms of SCR, and if not, how and why they are different. Many papers investigate the consistency of insurance regulation by comparing various aspects of insurance regulatory systems (Eling and Holzmueller, 2008; Cummins and Phillips, 2009; Eling, Klein, and Schmit, 2009; Holzmuller, 2009; Siegel, 2013). They provide an overview and qualitative comparisons of risk-based capital requirements for insurance industry in different economies, including the U.S., EU, Switzerland, and New Zealand, showing the inconsistency among different insurance regulatory systems. However, these comparisons are not based on the up-ta-date version for some economies. Two quantitative comparisons are provided by Braun, Schmeiser, and Siegel (2014), and Laas and Siegel (2016). Using a stylized asset portfolio representing the asset side of European life insurers or banks, Braun et al. (2014) show that Solvency II disproportionally penalizes the asset class of private equity comparing to Swiss Solvency Test; Laas and Siegel (2016) show that Basel III charges higher capital for banks than Solvency II for insurers having the same asset portfolio.

This paper extends the literature in the following ways. First, we extend the quantitative capital requirement comparison from the market and credit risk of the asset side (Braun et al., 2014; Laas and Siegel, 2016) to the underwriting risk of the liability side by defining additionally a stylized insurance portfolio, which enables us to comprehensively assess the capital requirements under respective regulations. Second, as far as we know, we are the first to compare the finalized C-ROSS, a modern regulatory system from the emerging market and the third largest insurance market,[1] with the up-to-date RBC incorporating SMI and the implemented version of Solvency II. This comparison provides important managerial implications to multinational insurers going to China and other emerging markets. Third, we innovatively define three stylized assets and insurance portfolios capturing different market structures in the U.S., EU, and China, respectively. Based on this unique empirical design, we find that the solvency system charges lower SCR for local insurers and provide

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[1] Here we consider the EU as one single insurance market (Eling and Holzmueller, 2008) and thus EU and the U.S. constitute two largest insurance markets.

one possible explanation for the regulatory inconsistency, i.e. the regulation's adaptation to the market structure, particularly on the liability side.

In this paper, we focus our analysis on non-life insurance companies because calculation of SCR for life and health insurers is much more complex. The remainder of this paper is structured as follows. In section 2, we qualitatively compare the standard approaches to calculate the SCRs in RBC, Solvency II, and C-ROSS. In section 3 and 4, we define three stylized accounting statements as representative companies in three markets and derive the parameters in three regulatory systems. Section 5 presents the numerical results. In section 6, we discuss one possible explanation for the inconsistency. Finally, we discuss our assumptions and robustness in section 7 and conclude in section 8.

2. Qualitative Assessment of Solvency Capital Requirements

Before conducting the numerical analysis, we analyze the regulatory consistency through the qualitative comparison among RBC, Solvency II, and C-ROSS, based on the up-to-date regulatory guidelines (EIOPA, 2014a; CIRC, 2015b; NAIC, 2016). We find inconsistencies exist among different solvency system from four aspects, including the risk module classification, calculation of SCR for each risk modules, accounting principle, and the trigger of regulatory intervention. We describe the details of standard calculation process of RBC, Solvency II, and C-ROSS in Appendix A.

Risk Modules. Two main differences exist for the risk module classification. On the one hand, apart from market risk (asset risk), credit risk[2], and underwriting risk module, Solvency II includes operational risk into the overall SCR, while RBC[3] is with SMI and C-ROSS is with pillar II (Qualitative Supervisory Requirements). On the other hand, RBC does not take interest rate risk and spread risk into consideration, while Solvency II and C-ROSS do.

[2] The equity risk in RBC covers both the equity risk and property risk of Solvency II, while the equity risk in Solvency II covers equity risk and real estate risk of C-ROSS. Therefore, to make it convenient to compare the SCR for each risk module, the equity risk mentioned below covers equity risk under RBC, equity risk and property risk under Solvency II, and equity risk and real estate risk under C-ROSS.

[3] When implementing Solvency Modernization Initiative (NAIC, 2013), RBC has made some modifications. Proposals about calculating SCR for catastrophe risk and operational risk has been adopted. However, currently, the operational risk and catastrophe risk is for informational purposes only and don't have impact on the company's actual RBC SCR, based on which the regulator decides to whether take actions or not (NAIC, 2016).

TABLE 1

Qualitative Comparison of Solvency Capital Requirements

		RBC (with SMI)	Solvency II	C-ROSS
Risk Modules[d]	Operational Risk	Yes (but for informational purpose only[a])	Yes	Yes (but only in Pillar II[b])
	Spread Risk	No	Yes (categorized into market risk)	Yes (categorized into credit risk)
	Interest Rate Risk	No	Yes	Yes
Calculation[d]	Methedology	Risk factor method	Scenario method	Risk factor method and scenario method
	Interest Rate Risk	Not considered	Both asset side and liability side are considered. Risk factor is dependent on risk-free interest rates.	Only asset side is considered. Risk factor is independent of risk-free interest rates.
	Default Risk	A simple formula	A complex formula	A simple formula
	Underwriting Risk	Considering lines of business diversification effect Risk factor is independent on the volume of risk exposure.	Considering both geographic and lines of business diversification effects Risk factor is independent on the volume of risk exposure.	Considering lines of business diversification effect Risk factor is decreasing with the increase of volume of risk exposure.
Accounting Principle		Book value based on Statuary Accounting Principle	Market value specified by Solvency II	Book value based on Chinese Accounting Standards
Trigger of Regulatory Intervention	Ratio of available capital to SCR that triggers regulatory action[c]	150%	100%	100%

Notes: This table summarizes the differences among the three solvency systems from four aspects, including the risk module classification, calculation of SCR for each risk modules, accounting principle, and the trigger of regulatory intervention.

[a] RBC is being modernized via SMI and operational risk is only for informational purposes currently.

[b] Pillar II refers to qualitative supervisory requirements.

[c] The regulatory action means that the regulator are required to examine the insurers and start to take actions aimed at restoring the insurer to a healthy condition.

[d] Only the risk modules which are different among systems are listed.

Calculation. For the same risk modules and sub-modules, inconsistency may arise due to different calculation process, including the calculation methods and parameter settings. For each risk module, RBC formula calculates SCR based on risk factor model and Solvency II on scenario method.

C-ROSS calculates the SCR based on scenario method for catastrophe risk sub-module and based on risk factor method for other sub-modules.

For market risk and credit risk module, with regard to the interest rate risk sub-module, there are two main differences between Solvency II and C-ROSS. On the one hand, Solvency II accounts for the insurance liabilities' interest rate sensitivity and C-ROSS only considers the interest rate sensitivity of the assets. On the other hand, when calculating the SCR for the asset side, the shocks under Solvency II depends on the current risk-free interest rates while independent under C-ROSS. Regarding the default risk module, the formulas under RBC and C-ROSS are much simpler than Solvency II (see Appendix A).

For underwriting risk module, Solvency II offers opportunities to reduce capital requirement due to diversification of the insurance portfolio by geographic area and by line of business, while RBC and C-ROSS consider the diversification of business lines only. Besides, Solvency II and C-ROSS calculate the diversification effect based on the distribution of the insurance portfolio while RBC only takes the ratio of largest line into consideration. Apart from these, C-ROSS proposes an excess-regressive method, where the risk factor decreases as the risk exposure increases while RBC and Solvency II have no such design, where the risk factor is independent of the volume of risk exposure.

Accounting Principle. The same risk module classification, calculation formula, and parameter setting lead to the same SCR only if the same accounting principle is applied to determine asset and liability values. As the base of calculating SCR, RBC and C-ROSS use the book value based on Statuary Accounting Principle (SAP) and Chinese Accounting Standards (CAS), respectively, and Solvency II uses the market value. Two key differences arise due to the different choices of accounting principle. For the asset side, RBC and C-ROSS require to use both fair value (including the equity assets) and amortized cost (including bond assets with investment-grade rating). For the assets carried at fair value, value of the assets required by RBC and C-ROSS is to a large extent in line with economic value required by Solvency II (Peng and Smith, 2010; Casualty Actuarial Society, 2012; Al-Darwish et al., 2014), but different with respect to assets carried at amortized cost. For the liability side, Solvency II and C-ROSS require to discount reserves while RBC not. Ideally, when calculating the

SCR for each company under the three systems, we should adjust the values in accordance with the required accounting principle. However, companies usually report the annual values based on one accounting rule. Thus in our numerical analysis, we abstract the differences in the valuation of assets and liability and then calculate the SCR based on the stylize portfolio shown in Table 2. We do robustness test in section 7, which shows the simplification does not change our conclusions.

Trigger of Regulatory Intervention. Depending on the ratio of available capital to capital requirements, different levels of regulatory intervention may be triggered, including that no action is required, that insurers has to submit a report, that the regulator may issue a corrective action against the insurer, that the regulator may require the liquidation of the insurer, and that regulator must require the liquidation of the insurer. To make the capital requirement comparable, we use the capital requirement, below which the regulatory begins to have rights to take corrective action against the insurers, as the SCR. Thus according to the three systems, the 1.5 times the SCR under RBC, the SCR under Solvency II, and SCR under C-ROSS is what we want to compare. Thus in section 5, for comparability, the results under RBC have been modified by multiplying 150%, while the results under Solvency II and C-ROSS are not modified.

3. The Market Structure: Stylized Asset and Insurance Portfolios

As a basis for the implementation and numerical comparison of the SCR, we define the asset portfolio and insurance portfolio of a stylized non-life insurer in the U.S., EU, and China market, respectively (see Table 2), following Laas and Siegel (2016). The creation of the three companies is based on the average composition of asset portfolio and insurance portfolio in respective markets in 2014. We name the three companies as Company U.S., Company EU, and Company CN, respectively.

TABLE 2

Stylized Asset and Insurance Portfolio

Panel A Asset Portfolio

Company	U.S.		EU		CN	
	Value	%	Value	%	Value	%
Total	*1,000*	*100*	*1,000*	*100*	*1,000*	*100*
Fixed Income Assets	614.6	61.4	574.8	57.45	417.2	41.7
Gov. Bonds	349.8	35.0	334.2	33.4	38.3	3.9
Corp. Bonds and Loans	264.8	26.4	240.6	24	378.9	37.8
Equity	231.2	23.1	183.3	18.3	75.9	7.6
Stocks	214.5	21.5	163.3	16.3	75.8	7.6
Alternative Investment	16.7	1.7	20.0	2.0	0.05	0.01
Cash and Deposit	59.8	6.0	36.9	3.7	336.6	33.7
Real Estate	5.5	0.5	30.1	3.0	41.3	4.1
Non-Investment Assets	88.8	8.9	175.0	17.5	129.0	12.9
Reinsurance Assets[a]	8.0	0.8	78.0	7.8	76.9	7.7
Debtors[b]	80.8	8.1	97.0	9.7	52.1	5.2

Panel B Insurance Business Portfolio

Company	U.S.		EU		CN	
	Value	%	Value	%	Value	%
Net Premium Written	*279.0*	*100*	*300.0*	*100*	*606.0*	*100*
Motor liability	83.7	30	72.2	24	269.7	45
Other motor	50.2	18	56.8	19	200.6	33
Property	83.7	30	90.0	30	41.8	7
Liability	41.9	15	33.0	11	25.5	4
Miscellaneous[c]	19.5	7	48.0	16	68.5	11

Panel C Insurance Liability Portfolio

Company	U.S.		EU		CN	
	Value	%	Value	%	Value	%
Reserves	*465.9*	*100*	*546.3*	*100*	*541.1*	*100*
Outstanding Claims	333.1	71	427.4	78	279.7	52
Motor liability	106.6	23	140.2	25	123.4	23
Other motor	3.3	1	47.9	9	87.0	16
Property	50.0	11	76.9	14	19.6	4
Liability	149.9	32	116.3	21	17.9	3
Miscellaneous	23.3	5	46.2	8	31.9	6
Unearned Premium	132.8	29	118.9	22	261.3	48

Notes: This table presents the asset portfolio and insurance portfolio of three representative companies with total asset value of 1000 USD million, whose portfolios capture asset, liability, and insurance market portfolio structure in the three markets, respectively. All absolute values are given in USD million. The asset portfolio and insurance portfolio are used to calculate the SCR under three solvency systems.

[a] Reinsurance assets refer to reinsurers' share of reserves.

[b] Debtors refer to insurance receivables including premiums receivable.

[c] Miscellaneous insurance includes lines of guaranty, credit, marine, and agriculture.

The value of total assets is set at USD 1,000 million, the approximate upper quartile of total assets of U.S. and EU non-life insurers in 2014[4], where the upper quartile is calculated using Orbis Database. Then the net premium written, premium earned, total reserve, and outstanding claim reserve are calculated using the net premium written to total assets ratio, premium earned to total assets ratio, insurance liability to total assets ratio, and outstanding claim reserve to total assets ratio, respectively.

We leverage the following three sources to construct the asset portfolio and insurance portfolio: (1) the industry report (NAIC, 2015; EIOPA, 2015; CIRC, 2015c), which include general and financial information of non-life insurer in U.S., EU, and China; (2) Orbis Database, based on which we calculate net premium written to total assets ratio, premium earned to total assets ratio, insurance liability to total assets ratio, and outstanding claim reserve to total assets ratio; (3) annual report of representative non-life insurer[5], based on which we appropriate the structure of sub-portfolio, modified duration[6], and the credit rating of counterparties.

Asset Portfolio

We divide the total assets into five classes that are cash and deposit, bond investment, equity investment, real estate, and non-investment assets, considering that these classes are the five major asset classes for companies in all three markets.[7] Following Braun et al. (2017), Company U.S., Company EU, and Company CN exclusively invests in USD-denominated, EUR-denominated, and CNY-denominated assets, respectively. We assume that the portfolio weights and subtypes of each asset class vary among three companies. The asset portfolio in Table 2 represents a stylized version of the three companies based on the reported values.

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[4] We do not use the distribution of total assets of Chinese insurers. Because the upper quartile of total assets of Chinese insurers is significant bigger than insurers in U.S. and EU due to the market entry mechanisms in China, which requires the minimum assets.

[5] For China, PICC is the largest non-life insurance company in China with a market share over 33% in the past a few years and it has adequate representation of non-life insurance industry in China (Sun, Suo, and Zheng, 2007). For U.S. Travelers is one of the largest non-life insurance companies. For EU, following Hoering (2013), we refer to several non-life insurance companies whose investment strategies associated with non-life business are available, including NN Schade, RSA, and AXA.

[6] For the modified duration for fixed income assets and deposits, we refer to the modified duration of representative companies or estimate using EC's (2015) method based on the maturity of bonds when the modified duration is unavailable.

[7] We combine loans into bond investment. In non-life insurance, most of the loans are categorized as loans other than mortgage loans. Under RBC and Solvency II, the calculation of SCR for loans and corporate bonds have no differences. Although the risk factors differ under C-ROSS, the differences are less than 0.02. Therefore, we use the weighted average risk factor of corporate bonds and loans as the effective risk factor for corporate bonds.

Fixed-income asset is the largest asset class for all three companies, with two sub-classes including government bonds and corporate bonds. For corporate bond, following Braun et al. (2017), we only consider bonds with investment-grade rating[8]. Regarding equity assets, the sub-classes include stocks and alternative investment, where the alternative investments include hedge funds and private equity. For cash and deposit asset, the proportion of cash is 100%, 38.3%, and 78.5% for Company U.S., Company EU, and Company CN, respectively, which is assumed to be deposited at banks with investment-grade rating following Laas and Siegel (2016). The proportions of cash and deposit and equity differ a lot between Company CN and the other two companies. Due to the severe financial constraints as a result of imperfect capital market in emerging market, Chinese insurers tend to hold relatively more cash and less equity for precautionary purpose (Feng and Johansson, 2014). With a conservative investment strategy, Company CN behaves badly in the return of investment, which restricts the growth of insurers. For real estate, following Braun et al. (2014), because we do not have any details on the constituent positions, the structure of each sub-portfolio is assumed to equal that of a house price index, which are HPI in U.S., HPI in EU, and average selling price of commercialized building index in China, respectively. The indexes give the annual growth rate of 5.3%, 2.03%, and 1.39%, respectively, according to Federal Housing Finance Agency, Eurostata, and National Bureau of Statistic of China, respectively. Within non-investment assets class, the sub-classes comprises of reinsurance assets[9] and debtors[10], considering they are the two main sub-classes apart from investment assets for companies in all three markets.

Insurance Portfolio

We abstract five lines of business for Company U.S., Company EU, and Company CN. Motor liability insurance, other motor insurance, property insurance, and liability insurance are the 4 largest lines for non-life insurance in all three markets. The other lines are then combined into miscellaneous category,

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[8] Since the non-life insurance companies in U.S., EU, and China allocate about 84 %, 99 %, and 87 % to the three highest rating classes of Standard & Poor's, respectively, the simplification is reasonable.
[9] Reinsurance assets refer to reinsurers' share of unearned premium reserves, and loss and loss adjustment expense reserves
[10] Debtors refer to insurance receivables including premiums receivable, agents' balances, and receivables from reinsurers.

the main lines belong which includes lines of guaranty, credit, marine, and agriculture[11]. As mentioned above, under RBC and Solvency II the separate models are used for life, health, and property-liability insurers. Therefore, we do not consider the health insurance (including workers' compensation, which is classified in the health insurance model) in the insurance portfolio.

As seen in Table 2, four major differences exist among the insurance portfolio structures of three companies. First of all, motor insurance, including motor liability and other motor insurance is much larger in Company CN than in Company U.S. and EU. Motor insurance takes 77% in Company CN, which is only about 45% in Company U.S. and Company EU. Secondly, property and liability insurance in Company CN is only 11%, which is much lower than in Company U.S. (45%) and Company EU (41%). Thirdly, the net premium written is higher in Company CN due to the high ratio of net premium written to total assets in China, which is driven by the high ratio of net premium to reserve with two reasons. On the one hand, insurance business in China has a much shorter tail than in U.S. and EU. For example, the average settlement period of auto liability insurance in China is about 2 years, which is about 10-15 years in U.S. and EU. The short-tail liabilities are likely to result in low incurred but not reported (IBNR) claims because it may take a short period of time for the claims to be settled. On the other hand, with a special accounting system, the loss amount estimated is recorded as case reserve, which will be eventually included in the incurred loss directly and not be included in the technical reserve. Thus the ratio of reserve to premium is relatively smaller in China. Fourthly, insurance portfolio is also different slightly between Company U.S. and Company EU. The outstanding claims reserve of other motor insurance is quite low in U.S. compared with in EU and China. This is due to the standardize claims processing of other motor insurance in U.S.. Through the standardize claims processing, the claims are paid quickly and some claims are even paid when the adjuster provides the car accident estimation , which leads to a lower reserve.

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[11] To calculate the proportion of liability and property insurance in U.S., we use the ratio of liability portion in commercial multiple peril and the ratio of liability portion in commercial multiple peril in 2013 (Swiss Re, 2014) to approximate the respective ratio in 2014. Besides, we approximate using the proportion for net premium written because we do not have the information about premium earned and outstanding claims reserve for EU.

4. Parameter Calibration for the Market Structure

We refer to NAIC (2014), EIOPA (2014a), and CIRC (2015b) to derive the parameters used in the formula. Table 3 and Table 4 give an overview of the parameters derived for our portfolios under RBC, Solvency II, and C-ROSS. For assets with sub-portfolios, risk factors shown in Table 3 have been weighted averaged to reflect the effective factor.

Market Risk Module and Credit Risk Module

Regarding the interest rate risk sub-module, Solvency II provides an upward and downward shock for each maturity of the term structure. The fixed-income assets and liabilities are assumed to react to these shocks according to their durations. Following Braun et al. (2017), we assume that term structure for each of the currency zones (USD, EUR, and CNY) is flat and choose the risk free rate of the representative yield curves on December 31, 2014 at the same maturity as the fixed-income asset[12]. C-ROSS specifies different risk factors for assets overseas and for domestic assets. For the risk factor related with investment-grade rating, the average of risk factor for three highest rating classes is chosen (Laas and Siegel, 2016).

With respect to the equity risk sub-module, the risk factor for real estate is 10%, 25%, and 13%, under RBC, Solvency II, and C-ROSS, respectively, where the return rate and the location of the real estate is used under C-ROSS. For stocks and alternative investment, RBC specifies risk factors of 10% for both and Solvency II specifies a shock of 41.8% and 51.8%, respectively, equal to the base level plus asymmetric adjustment which is 2.83% on December 31, 2014 according to EIOPA (2016). C-ROSS specifies risk factors of 30% and 39% for stocks overseas and for stocks domestic, where the return rate is used to calculate the risk factor for domestic stocks[13], and provides a risk factor of 40% for alternative investment.

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[12] To be representative to the risk free rate each of the currency zones, in line with Laas and Siegel (2016), the representative yield curve for USD, EUR, and CNY are yield curve of US treasury bond, yield curve of AAA-rated euro area central government bonds, yield curve of Chinese treasury bond, respectively.

[13] C-ROSS specifies three different risk factors for stocks in Shanghai and Shenzhen motherboard, small- and medium-sized enterprise board, and growth enterprise board, respectively. For simplification, we use the average of the three risk factors weighted by respective board's market capitalization as the risk factor for stocks. Due to the high yield of China stock market in 2014, risk factor of 39% is relative high.

TABLE 3

Patameters Derived for Market Risk and Credit Risk

RBC (Risk Factors in %)	
Equity Risk	
Stocks	15
Alternative Investment	15
Real Estate	10
Default Risk	
Bonds	0.3
Cash and Deposit	0.3
Loans	0.3
Reinsurance Assets	10
Debtors	5

Solvency II (Parameters)				
Equity Risk	$s_i^{equ,1}$(in %)	$s_i^{equ,2}$(in %)		
	-41.8	-51.8		
Property Risk	s^{prop}(in %)			
	-25			
Interest Risk	$s_i^{int,u}$(in %)	$s_i^{int,d}$(in %)		
t = 2	70	-65		
t = 3	64	-56		
t = 4	59	-50		
t = 5	55	-46		
t = 6	52	-42		
t = 7	49	-39		
Spread Risk	Risk Factors (in %)			
Company U.S.	4.6			
Company EU	4.7			
Company CN	4.8			
Default Risk	PD (in %)	LGD		
		U.S.	EU	CN
Cash and Deposit	0.08	56	23	73
AA-rated Reinsurance Assets	0.01	0	21	0
A-rated Reinsurance Assets	0.05	7.4	5.2	77
Debtors		75	41	52

C-ROSS (Risk Factors in %)			
Company	US	EU	CN
Equity Risk			
Stocks	30	30	39
Alternative Investment	40	40	40
Real Estate	13	13	13
Interest Risk			
Government Bonds	7.6	7.6	5.5
Corporate Bonds	7.5	6.4	5.3
Spread Risk			
Corporate Bonds	5.1	6.5	4.3
Default Risk			
Reinsurance assets	59	59	13
Debtors	0	0	0
Cash and Deposit	0	2.5	0.8
Corporate Bonds	4.9	4.9	4.9

Notes: This table summarizes the input parameters for the calculation of the capital requirements for market and credit risks, including risk factors (given in percent), shocks (given in percent), PDs (default probabilities, given in percent), and LGDs (loss given defaults, given in USD million). $s_i^{equ,1}$, $s_i^{equ,2}$, s_i^{prop}, $s_i^{int.u}$, and $s_i^{int,d}$ are the shock for type 1 equities, shock for type 2 equities, shock for properties, upward shock for interest rate, and downward shock for interest rate, repectively. For default risk and interest risk under Solvency II, SCRs are calculated using formula (6) and formula (7) in Appendix A which incorporate PDs, LGDs, $s_i^{int.u}$, and $s_i^{int,d}$. For other risks, SCRs are obtained by multiplying the risk factors or shocks with the respective asset value. Besides, under Solvency II and C-ROSS, some risk factors depend on the sub-portfolio of the assets and thus are different among companies.

TABLE 4
Risk Factors and Standard Deviations Derived for Underwriting Risk

	RBC (Risk Factors in %)	Solvency II (Standard Deviations in %)	C-ROSS (Risk Factors in %)		
			U.S.	EU	CN
Motor liability					
Premium	22	8	9	10	10
Reserve	11	9	11	11	11
Other Motor					
Premium	15	8	9	10	10
Reserve	9	8	11	11	11
Property					
Premium	22	6	39	39	39
Reserve	14	10	63	64	64
Liability					
Premium	32	11	14	14	14
Reserve	24	11	45	42	42
Miscellaneous					
Premium	36	10	24	24	24
Reserve	25	15	36	38	36

Notes: This table summarizes the input parameters for the calculation of the capital requirements for underwriting risks. All values are given in percent. The SCRs under Solvency II are obtained by multiplying triple standard deviations with the respective volume related to premium or reserve, while SCRs under RBC and C-ROSS are obtained by multiplying the risk factors with respective volume related to premium or reserve. Besides, under C-ROSS, the risk factors depend on the volume of premium or reserve and thus are different among companies.

With regard to the spread risk sub-module, Solvency II does not require SCR for government bonds issued by EU countries or countries with AA-rating and above (and thus U.S. and China according to Standard & Poor's), while C-ROSS does not require any SCR for government bonds. For corporate bonds with investment-grade rating, the parameter is calculated using the averaged $s_i^{spr,0}$ and $s_i^{spr,1}$ specified for three highest rating classes by Solvency II and C-ROSS, respectively.

Regarding counterparty default risk module, the risk factors shown in Table 3 are the risk factors specified by RBC for each asset class. Under Solvency II, the default probability is specified according to credit rating[14] and loss given default is equal to the volume of respective assets. C-ROSS

[14] For the default probability related with investment-grade rating, the average of default probabilities for three highest rating classes 0.08% is chosen (Laas and Siegel, 2016).

specifies different risk factors for each asset class and risk factors shown in Table 3 are the weighted averaged ones using these risk factor according to the sub-portfolio.

Underwriting Risk Module

With regard to premium and reserve risk sub-module, RBC, Solvency II, and C-ROSS specify different lines of business and provide the parameter for each line of business based on their categorization. Some lines in the stylized company are divided into several lines under the categorization of solvency system, the parameter of which are estimated by averaging the parameters of the sub-lines. Under C-ROSS, the risk factor for each line is related to the characteristics of the company, including combined ratio and volume of the premium or reserve. Therefore different companies may have different risk factors under C-ROSS[15]. With respect to catastrophe risk sub-module, we simplify the calculation by multiplying the SCR for premium and reserve risk sub-module to a fixed ratio (Laas and Siegel, 2016), which refers to the provided in the report by NAIC, EIOPA (2011), and CIRC for RBC, Solvency II, and C-ROSS, respectively.

5. Results

Table 5 and Figure 1.1 present the SCRs for Company U.S., Company EU, and Company CN under RBC, Solvency II, and C-ROSS. The first two rows show the overall SCR with and without diversification effect discount due to different risk modules, respectively. When aggregating overall SCR and overall SCR without diversification effect discount, we do not take into account the operational risk and catastrophe risk under RBC because they are currently for informational purposes only. However, we reconsider operational risk and catastrophe risk for RBC in section 7, the results of which are consistent with our conclusions.

[15] Under RBC, because the stylized companies we consider represent the industry average, we assume that company average RBC loss and expense ratio is equal to industry average RBC loss and that company development factor is equal to industry average development factor. Following the formula predetermined by NAIC (see the formula in Appendix A), the parameter for each line under RBC is also independent of company.

TABLE 5

Results: Solvency Capital Requirements for the Stylized Portfolio

	RBC			Solvency II			C-ROSS		
Company	**US**	**EU**	**CN**	**US**	**EU**	**CN**	**US**	**EU**	**CN**
Overall SCR (With Diversification Discount)	113.6	112.0	184.9	209.3	208.2	265.4	174.5	189.0	125.0
Overall SCR (Without Diversification Discount)	175.1	159.3	220.1	262.6	265.2	316.0	225.9	247.4	149.5
Aggregated Market and Credit Risk	54.0[#]	41.7[#]	26.5[#]	118.2[#]	95.3[#]	88.4[#]	87.6[#]	93.4[#]	52.1[#]
Market Risk	53.8	40.5	24.1	112.7	88.2	82.4	77.6	61.6	34.4
Credit Risk	4.5[#]	9.8[#]	10.9[#]	17.3	20.3	17.4	28.0	58.9	32.9
Equity Risk	53.8	40.5	24.1	118.0[#]	75.2[#]	56.2[#]	69.0[#]	54.0[#]	31.0[#]
Interest Risk	-	-	-	15.0	6.5	18.3	46.5	37.3	19.9
Default Risk	4.5[#]	9.8[#]	10.9[#]	17.3	20.3	17.4	17.6	57.3	17.8
Spread Risk	-	-	-	12.1	7.3	28.1	13.3	10.2	13.7
Underwriting Risk	100.2[#]	98.7[#]	179.4[#]	123.0	138.3	205.4	119.8	132.2	94.0
Premium Risk	60.4	46.5	169.4	90.2	101.4	150.7	106.4	117.5	83.5
Reserve Risk	79.9	87.1	59.1						
Catastrophe Risk	43.9	47.9	32.5	64.0	72.0	107.0	34.5	38.1	27.1
Operational Risk	0.5	0.6	1.2	14.0	15.6	18.2	-	-	-

Notes: This table presents the solvency capital requirements (in USD million) for three representative companies under the RBC, Solvency II and C-ROSS standard approaches. The first two rows show the overall SCR with and without diversification effect discount due to different risk modules, respectively. The following rows shows the SCR for different risk modules and sub-modules.

The calculation of SCR is based on the stylized portfolio in Table 2. The value with [#] is the quasi-aggregated value we derive for comparability. Besides, the equity risk here covers equity risk under RBC, equity risk and property risk under Solvency II, and equity risk, real estate risk, and foreign assets risk under C-ROSS. The “-” means the solvency system does not take this risk into the calculation of SCRs. Under RBC, the catastrophe risk and operational risk are for informational purpose only, and thus we do not take these SCRs into consideration when calculating the overall SCR.

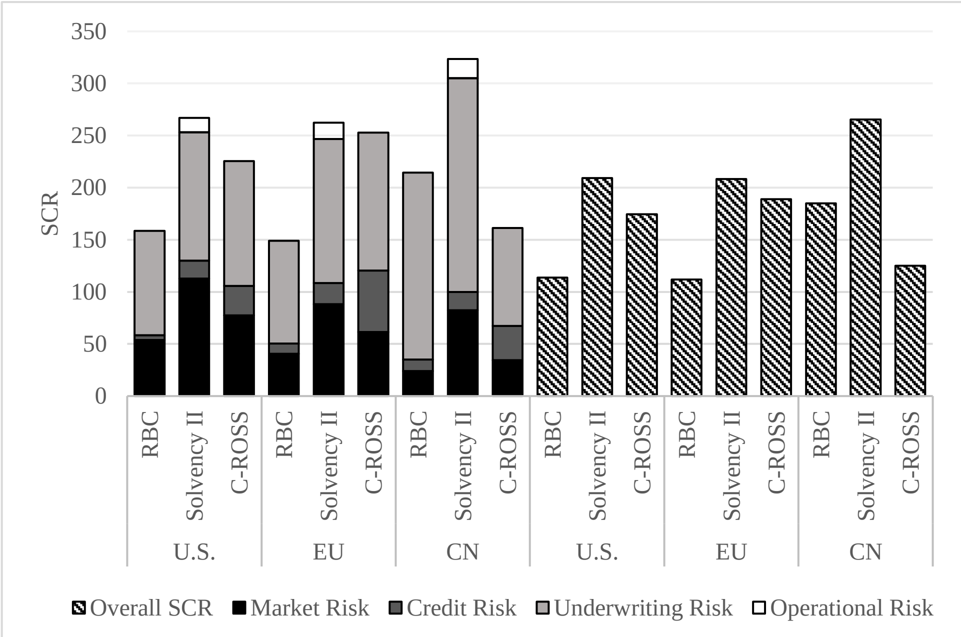

FIGURE 1.1 Solvency Capital Requirements for the Stylized Portfolio (Group by Companies)

Notes: This figure presents the solvency capital requirements (in USD million) for three companies (Company U.S., Company EU, and Company CN) under the RBC, Solvency II, and C-ROSS, respectively. The first 9 bars show the SCRs for each risk module without diversification effect discount between risk modules. The last 9 bars show the overall SCRs with the diversification effect discount between risk modules. We find that, for one company, overall SCRs under the three systems are different. Moreover, for one company, overall SCR under Solvency II is always the highest.

The numerical results show the inconsistency among RBC, Solvency II, and C-ROSS, where the three systems charge different SCRs even for the same company. On the one hand, when comparing the SCRs for one company under different systems, we find that, for each company, overall SCR under Solvency II is always the highest. For Company U.S. (Company EU or Company CN), the overall SCR under Solvency II is 84% (85% or 43%) larger than the SCR under RBC and 20% (12% or 63%) larger than the SCR under C-ROSS.

The highest SCR under SII is driven by equity risk sub-module and operational risk module. The inconsistencies of SCR for equity risk sub-module explains most inconsistencies of overall SCRs, which is due to the highest risk factor specified by Solvency II. As seen from Table 3, for equity risk, the shocks under Solvency II is 41.8 percent and 51.8 percent (for type 1 equities and type 2 equities, respectively), which is much larger than the 15 percent under RBC and the 13-39 percent under

C-ROSS. Besides, by considering operational risk in SCR, the overall SCR for Company U.S. (Company EU or Company CN) under Solvency II is increased by 8.0% (8.1% or 8.2%).

On the other hand, for one company, although the overall SCRs under RBC and C-ROSS are different, we find that RBC does not always charge higher or lower than C-ROSS. For Company U.S. and Company EU, the SCR under C-ROSS is larger than under RBC. For Company CN, the SCR under RBC is larger than under C-ROSS.

Our results are in line with the former researches in the sense that inconsistencies exit among different solvency systems. Braun et al. (2014) find that Solvency II charge different SCR for market risk from Swiss Solvency Test. We extend the finding by showing that the Solvency II also charges different SCR for market risk from RBC and C-ROSS. Besides, we find that the difference of SCR for market risk will lead to the difference of overall SCR.

6. One Possible Explanation for the Inconsistency among Solvency Systems

The inconsistencies among solvency systems may be explained by the regulation's adaptation to portfolio structure in respective markets. In this section, we first provide four theory-based motivations for regulators adapt to portfolio structure in respective markets and then present three pieces of empirical evidence. As shown in section 3, the portfolio structures vary among different markets. Thus by adapting to different portfolio structure in respective market, the inconsistencies solvency system arise among markets.

6.1 Theory-based motivations

The four motivations to adapt to portfolio structure in respective market include helping hand view (HHV) of regulator (Pigou, 1938), the grabbing hand view (GHV) of regulator (Stigler, 1971), policy objectives of regulator, and imperfect information. HHV and GHV are two alternative theories to determine the impact of market structure on regulatory setting, but through different paths (Masciandaro and Quintyn, 2008). As an elected politician, the HHV aims to please whole citizens, who are the voters, by maximizing the social welfare and preventing or correcting market failure (Munch and Smallwood, 1981). Because the solvency system may disproportionately require too high capital for some asset classes or insurance lines of business (Braun, Schmeiser, and Schreiber, 2017), solvency regulation distorts the market decision on asset portfolio and insurance portfolio. The distortion creates market inefficiencies and lower social welfare (Holzmueller, 2008). Therefore, to maximize the social welfare, the solvency system should be designed to minimize the distortion of market decisions (Cummins et al., 1993). In that case, the regulator should evaluate the portfolio structure before and after the introducing of solvency system and then develop the solvency system.

The GHV regulators tend to favor concentrated economic interests rather than the common voters to maximize the political support (Stigler, 1971; Jodan, 1972), which is the insurance industry in the case of insurance insolvency regulation. Insurance industry favors regulatory policies that benefit itself, e.g. lower SCR, and oppose policies that restrict itself (Meier, 1988). Thus the regulator avoids requiring too high capital for the asset class and insurance business line that the industry favors and have to make good use of the special features in the market in order to lower the capital requirements. In that case, the GHV regulators also design the solvency system based on the market portfolio structure.

Both of the two theories above treat regulators as passive and neutral arbiters, where the objective of regulator is merely to favor the interest group process (Meier, 1991). Other political theory argues that the regulator also has its own policy objectives, including monitoring the insolvency and risk management (Meier, 1988; Sabatier, 1988). Based on different objectives, the solvency systems are designed differently (Llewellyn, 2006). The objectives for regulation in finance are based on various market imperfections and failures (Llewellyn, 1999), which may be reflected through the maturity level and the structure of the designated market and be different in different markets. Therefore, solvency systems will be designed taking account the portfolio structure of the market which reflect the maturity level and the structure of respective market.

Besides, local regulators have less information about foreign companies and thus have the lower ability to detect whether a foreign business is risky or not (Holthausen and Rønde, 2005). With worse screening ability, the regulator tends to charge a higher capital requirements (Morrison and White, 2009). In that case, the regulator explores the local portfolio structure and verifies which assets' information is little and should be charged with higher capital requirements.

6.2 Empirical evidence

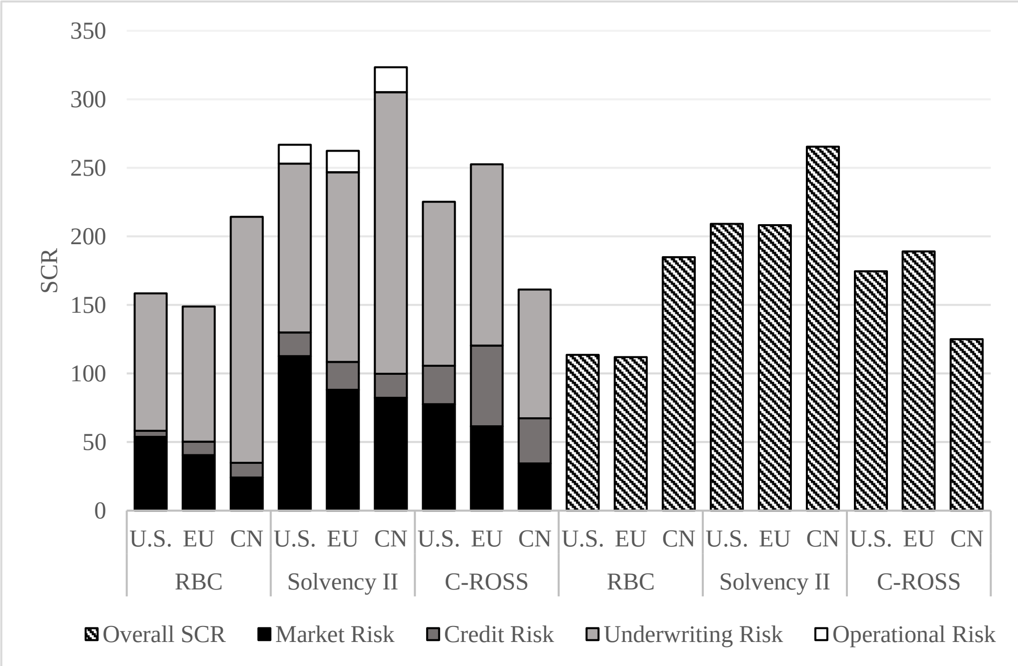

FIGURE 1.2 Solvency Capital Requirements for the Stylized Portfolio (Group by Solvency Systems)

Notes: This figure presents the solvency capital requirements (in USD million) for three companies (Company U.S., Company EU, and Company CN) under the RBC, Solvency II, and C-ROSS, respectively. The first 9 bars show the SCRs for each risk module without diversification effect discount between risk modules. The last 9 bars show the overall SCRs with the diversification effect discount between risk modules. We find that, driven by underwriting risk, RBC and Solvency II charges higher SCR for Company CN while C-ROSS charges higher SCR for Company U.S. and Company EU.

The qualitative comparisons in section 2 and quantitative comparison in section 5 provide 3 pieces of empirical evidence. Firstly, as seen in section 2, the three systems set some special mechanisms which is in coincidence with the characteristic of the portfolio structure in respective market, supporting regulation's adaptation to portfolio structure in respective market. RBC only considers the ratio of largest line when calculating the lines of business diversification effect, which is in line with the lower ratio of largest line in U.S.. Due to the mechanism, U.S. insurers get more discounts from lines of business diversification effect and thus get a lower SCR under RBC. Solvency II takes geographical diversification effect into consideration when calculating SCR for underwriting risk. This is in coincidence with that EU insurers usually operate internationally. By considering geographical diversification effect, EU insurers get discounts from operating internationally and thus get a lower

SCR under Solvency II. C-ROSS uses the excess-regressive method to calculate risk factors, which is in coincidence with the high absolute volume of premium in Chinese insurers. With the innovative method, Chinese insurers have the chance to get lower risk factors and thus a lower SCR under C-ROSS.

The second empirical evidence is that the solvency system charges lower SCR for local insurers. As seen in Figure 1.2, when comparing the SCRs for different company under the same systems, we find that Company CN is charged with lower SCR under C-ROSS while Company U.S. and Company EU are charged with lower SCR under RBC and Solvency II[16]. The numerical results imply that, even with the same asset size, three companies are charged with different SCRs under the same solvency system, where the local company and the company, whose portfolio structure is similar to the local company, get lower SCR. Besides, we also find that the pattern that solvency system charges lower SCR for local insurers is driven by underwriting risk. The numerical results support regulation's adaptation to portfolio structure in respective market, particularly on the liability side.

[16] The fact that companies with the same asset have different volume of premium in the three markets also explains the pattern of SCR for different company under the same systems. By calculating SCR for premium risk through multiplying the volume of premium to the respective parameter, company with higher premium (that is Company CN) tends to be charged with higher SCR.

TABLE 6

Parameter and Respective Proportion of Lines of Business and Asset Classes

	Parameter (in %)			% of respective total value		
	RBC	**Solvency II**	**C-ROSS**	**Company U.S.**	**Company EU**	**Company CN**
Asset Portfolio						
Stocks	15	51.8	39	21.5	16.3	7.6
Real Estate	10	25	40	1.7	2.0	4.1
Alternative	15	41.8	13	0.5	3.0	0.01
Insurance Portfolio						
Motor liability						
Premium	22	24	10	30	24	45
Reserve	11	27	11	23	25	23
Other Motor						
Premium	15	24	10	18	19	33
Reserve	9	24	11	1	9	16
Property						
Premium	22	18	39	30	30	7
Reserve	14	30	64	11	14	4
Liability						
Premium	32	33	14	15	11	4
Reserve	24	33	42	32	21	3
Miscellaneous						
Premium	36	30	24	7	16	11
Reserve	25	45	36	5	8	6

Notes: This table presentsshows the risk parameters and volume of respective asset classes and insurance lines of business in the market portfolio. All values are given in percent. For asset portfolio, only the parameters used to directly multiply the value of respective asset are shown in this table. For insurance portfolio, the risk parameter under Sovency II is the triple standard deviation, which is used to directly multiply the respective volume related to premium of reserve.

The third empirical evidence is the negative correlation relationship between risk parameters and volume of respective asset classes and insurance lines of business in the market portfolio, where the risk parameters are used to calculate the SCR by multiplying the volume of respective asset classes and insurance lines of business. Table 6 shows the parameter and volume of respective asset classes and insurance lines of business. For comparability, we only consider the asset class, of which the SCR is calculated by multiplying the risk parameters to value of the asset. We calculate the correlation coefficient between all 39 parameters and respective proportions shown in Table 6. We obtain the Pearson correlation coefficient of -0.34, which is significant at the 95% confidence level. Because both the larger parameter and larger proportion will lead to higher SCR for one asset class or lines of business, this result implies that the solvency system tend to set lower parameter for large proportion to avoid the high SCR. Thus the negative correlation coefficient also supports regulation's adaptation to market.

6.3 Discussion on Endogeneity

One may concern that last two pieces of evidence reflect insurers' adaptation to the regulation rather than the regulation's adaptation to insurance market. The stylized accounting statements defined in our paper is based on empirical data in 2014 when RBC has been enforced, C-ROSS was not drafted, and Solvency II has been drafted. Therefore, Chinese insurers could not adjust their asset portfolio and insurance portfolio according to the new capital requirements while insurers in U.S. and EU may rebalance their portfolios in line with the new capital requirements. Thus the concern about endogeneity may be justified for RBC and Solvency II, but not for C-ROSS. However, based on the existing researches, the possible endogeneity does not change our conclusions for RBC and Solvency II, either. The empirical researches show that many insurers (about 90% in U.S. and 85% in EU) already fulfil the new capital requirements regardless of the enforcement of new solvency standards due to binding capital constraints from their own internal model or due to their desire to satisfy rating requirements (Eling, Gatzert, and Schmeiser, 2008) and thus insurers do not have to change their behavior significantly when introducing the new capital requirements (Cheng and Weiss, 2013; Hoering, 2013). Therefore, the pattern that solvency systems charge lower SCR for the local company is at least partly due to the regulation' adaptation to insurance market. To further justify the argument above, we run an additional test. We repeat the numerical analysis presented in this paper using the data in 2009, when the draft of Solvency II is just adopted. We find that all results stay qualitatively the same and all conclusions hold.

The results add to the discussion on one global solvency standard. As shown in section 3, the portfolio structure varies among different market, especially between the emerging market and developed market. In that case, there is no single model which is able to adapt to all markets at the current stage. Thus, we agree with Llewellyn (2006) and Altuntas et al. (2015)'s opinion that the current market-specific solvency system may be not the worst case. The global standard, if desired, should also start with similar markets and should be flexible enough (Eling et al., 2009; Bomhard, 2010) to allow for market oriented adaptations.

7. Discussion of Assumptions and Robustness

Our calculations are based on various assumptions. A variation of these assumptions shows that the extent of discrepancy among the RBC, Solvency II, and C-ROSS charges may differ from our calculated values. The key results of higher total capital charges under Solvency II, and solvency system charges lower capital for the local companies are robust with respect to our assumptions.

Asset Concentration Factor under RBC. RBC charges the ten largest transactions double capital capped with a maximum risk factor of 0.3. We cannot consider this factor in the calculation due to the lack of information. However, we do the robustness test and find that our conclusions do not change even double the capital charges for market and credit risk under RBC.

Bond Size Adjustment Factor under RBC. RBC uses bond size adjustment factor to reflect the degree of diversification in the bond portfolio. Due to lack of information, we assume this factor to be 1 in the calculation. We do the robustness test by recalculating the SCRs using bond size adjustment of 0.9 and 2.5, which are the lower and upper bound for bond size adjustment factor, respectively. We find the results do not change.

Catastrophe Risk and Operational Risk under RBC. We also calculate the SCR under RBC considering the catastrophe risk and operational risk based on the version of RBC for informational purpose according to NAIC (2016). The results are shown in Table 5, as well. By aggregating the SCRs for each risk module, we obtain the overall SCRs of USD 129.5, 121.18, and 185.25 million for Company U.S., Company EU, and Company CN. Our results do not change.

Accounting Principle Differences. In our analysis, we abstract the difference of accounting principle. As we mentioned above, the accounting principle may matter in two aspects. From the aspect of liability, the reserve will lower when taking into account time value. Because of the short duration of nonlife insurance liability, we find the reserve only gets about 10% discount after considering time value using IRS's method (Almagro and Ghezzi, 1988). We estimate the reserve of Company U.S. with consideration of time value discount, as required by Solvency II and C-ROSS. Likely, we estimate the reserve of Company EU and Company CN without consideration of time value discount, as required by RBC. Using the modified reserve to recalculate the SCRs, we find our results qualitatively unchanged. From the aspect of assets, the amortized costs used for assets may substantially deviate from the market value required by Solvency II. For example, the amortized cost of the Allianz Group's held-to-maturity debt portfolio in 2014 is 16% lower than the portfolio's fair value (see Allianz Group, 2015). We find our results unchanged when the value of all bonds reduced by 16%.

8. Conclusion

Motivated by the authorities' goal and discussion of global consistency of regulatory systems, this paper explores the consistency of the solvency capital requirements of three risk based solvency systems, RBC standards, Solvency II, and C-ROSS. Firstly, we find inconsistencies do exist among solvency systems through qualitative and quantitative analyses. Our qualitative analyses reveal inconsistencies from four aspects, including the classification of risk modules (that is operational risk, interest rate risk, and spread risk), calculation methodology and formula of SCR for each risk module, accounting principle applied to determine the value of assets and liabilities, and the ratio of available capital to SCR that triggers regulatory action. Based on three stylized assets and insurance portfolios capturing different market structures in the U.S., EU, and Chinese, respectively, our quantitative analyses suggest that Solvency II charges higher SCR than RBC and C-ROSS, which is driven by the equity risk and operational risk.

Secondly, based on theory-based motivations, we explain the inconsistency among solvency systems by regulation's adaptation to portfolio structure in respective market. When the portfolio structures vary among different markets, by adapting to different portfolio structure in respective market, the inconsistencies solvency system arise among markets. We find three pieces of empirical evidence. The first is that, when calculating SCR, the three systems set some special mechanisms in coincidence with the characteristic of the portfolio structure in respective market. The second evidence is that C-ROSS charges Chinese insurers with lower SCR, while RBC and Solvency II charge both U.S. and European insurers with lower SCR. Companies with the same asset size are charged with different SCRs under the same solvency system, where the local companies and the companies whose portfolio structure is similar to the local company, get lower SCR. The third evidence is the negative correlation between risk factors and volume of respective asset classes and insurance lines of business in the market portfolio, where the risk factors are used to calculate the SCR by multiplying the volume of respective asset classes and insurance lines of business.

Our results contribute to the policy discussion on global standard. We find that portfolio structures are different among markets at current stage and that regulation adapts to respective market. Therefore, the global standard, if desired, should start among countries with similar market portfolio structure and should be flexible enough to allow for market oriented adaptations. If the global standard does not allow different markets to make adjustments in accordance with respective market portfolio structure, it may charge too high SCR for insurers in the market. Then, to avoid the high SCR, the insurers would change their optimal decision on asset portfolio and insurance portfolio. The distortion may create market inefficiencies and lower social welfare.

Moreover, we identify several aspects for future research. In the numerical analysis, firstly, we simplify the differences of accounting principle. Although our conclusions on the market-oriented regulation are robust with these simplification, differences of accounting principle deserve future investigations. Secondly, we only focus on the SCR of the three systems and do not discuss the eligible capital. Both the assessment and stratification (available capital under RBC; tier 1, tier 2, and tier 3 capital under Solvency II; core capital and supplementary capital under C-ROSS) of eligible capital are different among different systems. Thus, different definition of eligible capital will also lead to different solvency ratio. Thirdly, we use a few assumptions and approximations in this paper. These assumptions are reassessed once new information become available. One example is the linear correlation between the SCR for premium and reserve risk and SCR for catastrophe risk. Fourthly, we focus on capital requirement for the non-life industry, of which the most important risk is underwriting risk, while for life insurers market risk is the largest risk. Besides, life insurers hold less equity assets and more bond assets than non-life insurers. Based on the differences between life and non-life industry, the comparisons of the capital requirements among different systems for life industry is also interesting to conduct in the future research. Fifthly, both Solvency II and C-ROSS are meant to reduce pro-cyclicality of SCR. Under both systems, the risk factors for stock are lower in times of financial distress, which reduces the SCR under financial distress and thus reduces pro-cyclical behavior[17]. Future research may explore whether these mechanisms are effective to reduce pro-cyclical risk. Sixthly, apart from the quantitative supervisory requirements, qualitative supervisory requirements are also important to discuss. High solvency ratio does not necessarily mean financial security, because most fatal risks are not able to be resolved using capital requirement, which are evaluated through qualitative supervisory requirements.

[17] Besides, C-ROSS also plans to calculate the SCR for pro-cyclical risk. However, the concrete calculation method has not released yet.

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Appendix A Standard Approaches of Regulatory Systems

RBC

RBC requires the calculation of six separate capital charges (including R0, R1, R2, R3, R4, and R5) and a subsequent aggregation using formula:

$$\mathrm{SCR_{all}} = \mathrm{R0} + \sqrt{R1^2 + R2^2 + R3^2 + R4^2 + R5^2}. \tag{1}$$

R0 represents for the charge due to the risk from insurance subsidiaries. R1, R2, and R3 account for default risk due to fixed income securities, equity risk, and credit risk due to receivables, respectively. The R0, R1, R2, and R3 risk component are categorized as asset and credit risk component. R4 and R5 calculate SCR of reserve risk and premium risk, which are categorized as underwriting risk. For each of the risk component above, the SCR is calculated by multiplying the volume of each risk exposure to the risk factors given by regulator to various asset, premium, and reserve.

Asset and Credit Risk. RBC specifies assets subject to each risk component and provide different risk factor for each kind of assets. For the bond assets, the risk factor also differs based on the issuers' credit rating. The SCR of different assets that are subjected to the same risk module (R0, R1, R2, or R3) are summed to the capital charge for the risk module.

Underwriting Risk. RBC specifies 19 lines of business. In the underwriting risk component, the RBC requires the calculation of SCR for each line of business and a subsequent summarization. For each line of business i, the capital charge of reserve risk and premium risk is calculated using the following formula, respectively:

$$\mathrm{R4_i} = \mathrm{LAE_i} \cdot \left(\mathrm{AdjINCOME_i} \cdot (1 + \mathrm{CLRBC_i})\right) - 1), \tag{2}$$

$$\mathrm{R5_i} = NWP_i \cdot \max\{(\mathrm{AdjINCOME_i} \cdot \mathrm{CRBC_i} + \mathrm{CUER_i}) - 1, 0\}, \tag{3}$$

where $\mathrm{LAE_i}$ is the loss and expense reserves, $\mathrm{AdjINCOME_i}$ is the adjustment for investment income given by NAIC, $\mathrm{CLRBC_i}$ is the company loss and expense RBC percent which is equal to $\frac{1}{2}(\frac{\mathrm{CDF_i}}{IADF_i} \cdot \mathrm{ILRBC_i} + \mathrm{ILRBC_i})$, NWP_i is the current year's net written premium, $\mathrm{CUER_i}$ is the company-specific underwriting expense ratio, and $\mathrm{CRBC_i}$ is the company-specific RBC loss and expense ratio calculated as $\frac{1}{2}(\frac{\mathrm{CALE_i}}{IALE_i} \cdot \mathrm{IRBC_i} + \mathrm{IRBC_i})$. And $\mathrm{CDF_i}$ and $\mathrm{CALE_i}$ is company development factor and company average loss and expense ratio, respectively, calculated based on the company historical data using the method prescribed by NAIC (see Feldblum, 1996). Besides, $\mathrm{IADF_i}$, $\mathrm{ILRBC_i}$, $\mathrm{IALE_i}$, and $\mathrm{IRBC_i}$ are the industry average development factor, industry loss and expense RBC percent, industry average loss and expense ratio, and industry RBC loss and expense ratio, respectively, provided by the NAIC for business line i. The SCR for reserve risk (R4) is equal to the product of a reserve loss concentration factor and the summarization of $\{\mathrm{R4_i}, \mathrm{i} = 1, \dots, 19\}$, where the loss concentration factor is calculated based on the reserve of the largest line using a prescribed formula. Likely, the SCR for premium risk (R5) is equal to the product of a premium loss concentration factor and the summarization of $\{\mathrm{R5_i}, \mathrm{i} = 1, \dots, 19\}$, where the loss concentration factor is calculated based on the premium of the largest line using a prescribed formula.

Solvency II

The calculation of the capital charges comprise several modules (including market risk module, counterparty default risks module, underwriting risk module, and operational risk module) and sub-modules. To reflect diversification effects, the requirements for different modules or sub-modules are aggregated by means of the general square-root formula:

$$\mathrm{SCR_{agg}} = \sqrt{\sum_{ij} Corr_{ij} SCR_i SCR_j}. \tag{4}$$

where SCR_i and SCR_j denote the charges for the different modules (or sub-modules) that have to be aggregated and $Corr_{ij}$ the prescribed correlation between the risks in (sub-)modules i and j. For each risk sub-module, the SCR is calculated using scenario-based approach.

Market Risk Module. The Solvency II market risk module consists of interest rate risks, equity risks, property risks, spread risks, concentration risks, and currency risks. For sub-module M, SCR is defined as the resulting loss in BOF due to specific shocks $\mathrm{s_M}$, where both the assets $\mathrm{A_i}$ and liabilities $\mathrm{L_j}$ covered by sub-module M are taken into account:

$$\begin{aligned} \mathrm{SCR_M} &= \max\{\Delta(A - L)|s_M; 0\} \\ &= \max\{\textstyle\sum_{i \in M} \Delta A_i | s^M - \sum_{j \in M} \Delta L_j | s^M ; 0\} \end{aligned} \tag{5}$$

The respective shocks under equity risk, property risk, and spread risk sub-modules do not influence the liabilities. For property risks, Solvency II defines a shock $\mathrm{s}^{\mathrm{prop}}$ and $\Delta A_i|s^{prop} = \mathrm{s}^{\mathrm{prop}} \cdot \mathrm{A_i}$. The SCR for equity risk is equal to the aggregation of two separate SCRs for "type 1 equities" and "type 2 equities". For each equity type k = 1, 2, the SCR is calculated using $\Delta A_i|s^{equ,k} = \mathrm{s}^{\mathrm{equ,k}} \cdot \mathrm{A_i}$, where $s^{equ,k}$ is the predetermined shock. Each shock is equal to a base level stress plus a symmetric adjustment (see EIOPA 2014a). For spread risk sub-module, the spread stresses $s_i^{spr,0}$ and $s_i^{spr,1}$ depend on the instrument i (e.g., the issuer's credit quality). For bond with a modified duration $\mathrm{MD_i}$ in the range $(5\mathrm{k};\ 5(\mathrm{k}+1)], \mathrm{k} \in \{0, 1, 2, 3, 4\}$, SCR is $\Delta A_i|s^{equ,k} = [s_i^{spr,0} + s_i^{spr,1} \cdot (\mathrm{MD_i} - 5 \cdot \mathrm{k})] \cdot \mathrm{A_i}$.

The interest rate risk module considers an upward shock $s_i^{int,u} > 0$ and a downward stress $s_i^{int,d} < 0$, which are increases or reduces the risk-free interest rate $\mathrm{r_t}$ at each maturity t. The SCR of interest rate risk is equal to the maximum of the loss of BOF due to the two shocks where the loss is calculated using Formula (5) (see also Gatzert and Martin, 2012).

*The Counterparty Default Risk Module***.** For the counterparty default risk module, the system requires the calculation of two separate capital charges for type 1 exposures and type 2 exposures [18] and a subsequent aggregation using Formula (4). The capital charge $\mathrm{SCR_{def,1}}$ for type 1 exposures and $\mathrm{SCR_{def,2}}$ type 2 exposures are calculated using Formula (6) and Formula (7), respectively. (see also EIOPA, 2014a).

$$\mathrm{SCR_{def,1}} = \begin{cases} 3\sqrt{V},\ if\ \ \sqrt{V} \leq 7\%\, LGD \\ 5\sqrt{V},\ if\ \ 7\% \leq \sqrt{V} \leq 20\%\, LGD \\ \mathrm{LGD},\ if\ \ 20\%\, LGD \leq \sqrt{V} \end{cases} \tag{6}$$

$$\mathrm{SCR_{def,2}} = 0.9 \sum_{i \in M^{def,2>3m}} LGD_i + 0.15 \sum_{\in M^{def,2\leq 3m}} LGD_i \tag{7}$$

where LGD is the sum pf the loss given default LGD_i of all type 1 exposures, V is the variance of the loss distribution of type 1 exposures, and $M^{def,2>3m}(M^{def,2\leq 3m})$ is the subset of type 2 exposures from debtors that have been outstanding for more than 3 months (less than 3 months).

[18] The class of type 1 exposures covers the exposures which may not be diversified and where the counterparty is likely to rated, while the class of type 2 exposures covers the exposures which are usually diversified and where the counterparty is likely to unrated.

Underwriting Risk Module. The non-life underwriting risk consists of three sub-risks: premium and reserve risk, lapse risk, and catastrophe risk[19]. Under the scenario approach, the SCR for non-life premium and reserve risk is determined as follows:

$$\mathrm{SCR}_{\mathrm{PR}} = 3 \times \sigma \times V, \tag{8}$$

where V is the volume measure and σ is the combined standard deviation for non-life premium and reserve risk. Solvency II specifies 9 lines of business and provides the standard deviation for each line of business σ_s. The volume measure for each line V_s is obtained by using the prescribed formula which incorporate the expected present value of premium to be earned after the following 12 months, the maximum of premium to be earned during the following 12 months and premium earned during 12 months, and the best estimate foe claims outstanding for each geographical segment. Then based on $\{\sigma_s\}$ and $\{V_s\}$, V and σ are calculated using a predetermined formula. For lapse risk and catastrophe risk, Solvency II specifies several shocks, the SCR is equal to the resulting loss in BOF due to prescribed shocks using Formula (5).

Overall SCR. To calculate the overall SCR, one has to aggregate the module-specific SCR to the Basis Solvency Capital Requirement (BSCR) by means of Formula (4) and calculate SCR for intangible asset risks (not considered here). Then SCR for operational risks, which is calculated using a formula based on BSCR and the earned premium, is added to the BSCR (see EIOPA, 2014a).

C-ROSS

The calculation of the SCR under C-ROSS comprise several modules (including market risk module, credit risks module, and underwriting risk module) and sub-modules. The requirements for different modules or sub-modules are aggregated using Formula (4).

Market Risk Module. The Solvency II market risk module consists of interest rate risks, equity risks, real estate risks, foreign assets risks, and currency risks. The SCRs of these sub-modules are calculated using a factor-based approach and aggregated to $\mathrm{MC}_{\mathrm{mkt}}$ by means of a formula of type (4). Under the factor-based approach, the assets exposed to risk M are subject to specific risk factor RF

[19] The SCR for lapse risk is about 1 % of the SCR of non-life underwriting risk (EIOPA, 2011).

and the required capital $\mathrm{MC_M}$ (before diversification) is defined as the product of risk exposure and RF. RF is calculated based on base factor $\mathrm{RF_0}$ and characterization factor K, using the following formula:

$$\mathrm{RF} = \mathrm{RF_0} \times (1 + K). \quad (9)$$

For each risk submodule in market risk module, C-ROSS specifies the asset subject to the sub-risk and provides calculation method of $\mathrm{RF_0}$ and K.

For interest rate risk sub-module, assets sensitive to interest are covered in this sub-module, where $\mathrm{RF_0}$ is equal to the product of the modified duration and a factor linearly depend on the modified duration. For equity risk sub-module, the equity asset invested in China are subject to this risk. C-ROSS divides the equity into several sub-types and provides $\mathrm{RF_0}$ and K for each sub-type, where the $\mathrm{RF_0}$ and K depend on the return rate for some sub-types. For real estate risk sub-module, $\mathrm{RF_0}$ is determined by the accounting method while K is influenced by the return rate, the ratio of real estate to total assets, and the location of the real estate. For foreign assets risks, the assets invested overseas are subject to this risk. C-ROSS specified different $\mathrm{RF_0}$ for equity assets and fixed income assets. The K varies between the assets invested in developed market and developing market. The SCR for fixed income assets and equity assets are then aggregated to the capital charges of foreign assets risks using Formula (4).

Credit Risk Module. The C-ROSS credit risk module consists of spread risk and counterparty default risk. Under both risk sub-module, C-ROSS specifies several kinds of assets covered by each sub-module and calculates the SCRs using Formula (9). For spread risk sub-module, $\mathrm{RF_0}$ is calculated as the product of the modified duration and a factor linearly depend on the modified duration, where the linear function is influenced by the issuers' credit rating. For counterparty default risk submodule, C-ROSS provides $\mathrm{RF_0}$ and K which may incorporate issuers' credit rating and maturity, among others. After calculating the SCR for spread risk and counterparty default risk separately, the SCR for credit risk is aggregated by means of Formula (4).

Underwriting Risk Module. The C-ROSS underwriting risk module consists of premium risk, reserve risks, and catastrophe risk. Firstly, the SCRs of these sub-modules are calculated separately, where the

SCRs of premium risk and reserve risks sub-module are calculated using a factor-based approach and the SCR of catastrophe risk sub-module is calculated using a scenario-based approach. Secondly, the SCRs of premium risk and reserve risks are aggregated to the SCR of premium and reserve risk by means of a formula of type (4). Thirdly, the SCR for underwriting risk module is calculated by aggregating the capital charge of premium and reserve risk and catastrophe risk by means of a Formula (4).

To calculate the SCR for premium risk sub-module and reserve risk sub-module, C-ROSS specifies 10 lines of business. For each line, the SCR for premium risk sub-module and reserve risk sub-module is calculated by means of Formula (4) and based on an excess-regressive method, where the RF_0 decreases as the risk exposure increases. The risk exposure in the premium risk sub-module and reserve risk sub-module are defined as net premium written in the past 12 months and reserve for outstanding claims, respectively. C-ROSS takes combined ratio and nonproportional reinsurance into consideration when determining K of premium risk and take into account deviation of reserve estimate when calculating K of reserve risk. For catastrophe risk, the SCR is calculated as the 99.5 percent value at risk of the BOF under the scenario given by C-ROSS.

Overall SCR. After calculating the capital charges for all risk modules, the final SCR has to be determined. For this, the overall SCR are obtained by aggregating the module-specific charges by means of Formula (4).