Risk-Based Capital — Calibration of LOB Diversification in Underwriting Risk Charges

Report 14 of the CAS Risk-Based Capital (RBC) Research Working Parties
Issued by the RBC Dependencies and Calibration Working Party (DCWP)

Abstract: In this paper we analyze the Line of Business (LOB) diversification elements of the RBC Formula.

We compare the diversification credit produced by the NAIC Property/Casualty RBC Formula to the indicated diversification credit, i.e., the observed reduction in risk[1] with increasing diversification. For the larger/more diversified companies, with the bulk of the reserves/premium and receiving the bulk of the diversification credit, we find that:

- The data supports the approach in the RBC Formula, i.e., the data supports a diversification credit that is linear with respect to 100% minus the percentage of reserves/premium in the largest line of business, by company.
- The indicated maximum diversification credit is at least at least 50%, for premium risk and reserves risk, rather than the 30% maximum credit in the 2010 RBC Formula.

Three natural alternatives to the diversification approach in the RBC Formula are the correlation[2] matrix approach, the Herfendahl-Hirschman Index (HHI) approach, and the RBC approach applied to risk amounts rather than reserves/premium volume. We apply some simple tests of the extent to which each of these approaches fits the data. With our tests, the correlation approach is better than the approach in the RBC Formula for reserves, but the reverse is the case for premium. More interestingly, the RBC approach applied to risk amounts rather than reserves/premium volume is better than the approach in the RBC Formula for both premium and reserves.

This is one of several papers being issued by the CAS RBC Dependencies and Calibration Working Party (DCWP).

Keywords: Risk-Based Capital, Capital Requirements, Analyzing/Quantifying Risks, Assess/Prioritizing Risks, Integrating Risks, Diversification, Correlation

1. Introduction

The NAIC Property/Casualty RBC Formula (RBC Formula) has six main risk categories, $R_0 - R_5$. Underwriting risk is represented in two of these categories, R_4[3] and R_5, reserve risk and premium risk, respectively. The all-lines R_4 and R_5 values include a credit for diversification. The diversification credit in R_4 is based on the ratio of reserves for the LOB with the largest reserves to the total reserves. Similarly, the diversification credit in R_5 is based on the ratio of premium for the LOB with the largest premium to the total premium. We refer to this method of measuring diversification as the Company Maximum Line Percentage of Business or the

[1] Risk, in our analysis, is 87.5th percentile Reserve Runoff Ratio, for reserve risk, and the 87.5th percentile accident year ultimate operating loss (AYUL), for premium risk.

[2] We use the term correlation to describe a factor-based method for combining individual risks to produce risk measures for the combination of several risks. The source of the factor might be linear correlation, copulas or other techniques. In using this term, we do not intend to imply that the assumptions related to linear correlation are appropriate.

[3] When applied in the RBC Formula, the pure reserve risk component is combined with a portion of the reinsurance credit risk component. This paper deals with the pure reserve risk component of R_4.

CoMaxLine% Approach. We refer to the ratios as the $\text{CoMaxLine\%}_{\text{PREMIUM}}$ and the $\text{CoMaxLine\%}_{\text{RESERVES}}$, or CoMaxLine% generically, for either.

In this paper we evaluate the RBC Formula 30% Maximum Diversification Credit (MDC) and the assumption that diversification is proportional to 100%-CoMaxLine%.

We also evaluate alternatives to the diversification approach in the RBC Formula, e.g., the correlation[4] matrix approach, the Herfendahl-Hirschman Index (HHI) approach, and RBC approach applied to risk amounts rather than reserves/premium volume (CoMaxLine%-Risk).

In Section 2 we describe the nature of our risk data. In section 3 we evaluate the CoMaxLine% Approach. In section 4 we compare the performance of the CoMaxLine% Approach to the performance of the alternative approaches.

1.1 Terminology, Assumed Reader Background and Disclaimer

This paper assumes the reader is generally familiar with the property/casualty RBC Formula[5] and has a working knowledge of risk data and line of business risk factor calibration approach described in DCWP Reports 6 and 7.

In this paper we use the term diversification, rather than its complement,[6] concentration unless the context makes the alternative clearer.

Although the term multi-line insurance company is commonly used to refer to an insurer that is well-diversified across LOBs, in this paper we will use the term more broadly to refer to any company for which the diversification credit is greater than zero.

References to "we" and "our" mean the principal authors of this paper. References to "working party," and "DCWP" mean the CAS RBC Dependencies and Calibration Working Party.

The analysis and opinions expressed in this report are solely those of the authors, and are not those of the authors' employers, the Casualty Actuarial Society, or the American Academy of Actuaries.

DCWP makes no recommendations to the NAIC or any other body. DCWP material is

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[4] We use the term correlation to describe a factor-based method for combining individual risks to produce risk measures for the combination of several risks. The source of the factor might be linear correlation, copulas or other techniques. In using this term, we do not intend to imply that the assumptions related to linear correlation are appropriate.

[5] For a detailed description of the formula and its basis, see Feldblum, Sholom, NAIC Property/Casualty Insurance Company Risk-Based Capital Requirements, Proceedings of the Casualty Actuarial Society, 1996 and NAIC, Risk-Based Capital Forecasting & Instructions, Property Casualty, 2010.

[6] A company with a concentration ratio of 80% can equivalently be described as a having a diversification ratio of 20%, 100%-80%.

for the information of CAS members, policy makers, actuaries and others who might make recommendations regarding the future of the RBC Formula. We expect that the material will be used by the American Academy of Actuaries.

This paper is one of a series of articles prepared under the direction of the DCWP.

2. Risk Data

We describe our risk data in DCWP Reports 6 [7] and 7, [8] and we summarize the characteristics of that data below.

For each year-end (Initial Reserve Date), the reserve risk data consists of the reserve amount (Initial Reserve [9]) and reserve development data. We summarize the reserve development data into a Reserve Runoff Ratio (RRR). The RRR is the ratio of (a) movement in incurred loss and defense and cost containment expense (DCCE) from the Initial Reserve date to the most mature valuation date available to (b) the Initial Reserve for loss and DCCE. The ratios in that RRR calculation are net of reinsurance, from Schedule P, Parts 2 and 3, in the 1997-2010 Annual Statements, by LOB and by company for individual companies and DWCP-defined pools, as indicated.[10] Thus, each reserve data point is the Initial Reserve and RRR from a single Initial Reserve Date and LOB for a single company or DCWP-defined pool (LOB-Company-Initial Reserve Date). We have data for Initial Reserve dates 1987-2009.[11]

Similarly, the premium risk data consists of net earned premium (NEP) and accident year

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[7] http://www.casact.org/pubs/forum/13fforum/01-Report-6-RBC.pdf

[8] http://www.casact.org/pubs/forum/14wforum/Report-7-RBC.pdf

[9] Reserve for loss and defense and containment expenses, but not including adjusting and other expenses.

[10] The Risk Data points are filtered as we describe in DCWP Report 6 (on PRFs) and Report 7 (on RRFs). In brief, the main filters are that we exclude anomalous values; treat pool company data on a combined basis (DCWP-defined group pools); exclude Minor Lines data points (see Glossary); exclude the smallest LOBs data points, defined as those in smallest 15th percentile of LOB-size, by AY; exclude companies with less than 5 AYs of NEP; use values at the latest available maturity; and include companies regardless of whether they filed a 2010 Annual Statement (Survivorship Adjustment).

The runoff ratio includes movement related to "all prior year" element of Schedule P.

Those filters are largely the same as the filters used in the 2016 American Academy of Actuaries calibration report 2016 Update to Property and Casualty Risk-Based Capital Underwriting Factors http://www.actuary.org/files/publications/PC_RBC_UWFactors_10282016.pdf

[11] The most recent RRRs in our data are from the runoff on Initial Reserve Date December 2009, which represents one year of reserve development, from December 2009 to December 2010. There is one fewer year of reserve development than there are of AYs in that for the latest year, 2010, we have AY LRs, but no runoff on the 2010 Initial Reserve.

(AY) loss and loss adjustment expense ratios (LRs) for AYs 1988-2010, net of reinsurance, at the latest available maturity from Schedule P, Part 1, in the 1998-2010[12] Annual Statements, by LOB and by company or DCWP-defined pool, as indicated (LRs). Thus, each premium data point consists of the NEP and LR for a single AY and LOB for a single company or DCWP-defined pool (LOB-Company-AY).[13]

For this analysis of diversification, we also construct all-lines data points. For reserve risk, the all-lines Initial Reserve for each Company-Initial Reserve Date is the sum of the Initial Reserves for each of the company LOBs in the risk data. The all-lines RRR is the all-lines average RRR weighted by Initial Reserves by LOB. [14] For premium risk, the all-lines NEP for each Company-AY data point is the sum of the NEP for each of the company LOBs in the risk data. The all-lines LR is the all-lines average LR weighted by NEP by LOB.

There are 30,000 all-lines Company-Initial Reserve Date reserve risk data points and 29,000 all-lines Company-AY premium risk data points in the resulting all-lines data set. We categorize each of these points into size and diversification bands, as we describe below.

Company size bands

We measure company size based on all-lines Initial Reserve or all-lines NEP, for reserves and premium, respectively. We classify each company as being in one of five company size bands, selected so that 20% of the company data points are in each company size band. We label these company size bands A (smallest) through E (largest).

Company diversification bands

We determine the degree of diversification for each all-lines data point using the CoMaxLine%, correlation matrix, HHI or CoMaxLine%-Risk approaches, as appropriate for the analysis. [15] We use 6 diversification bands. Diversification band 0 is for monoline

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[12] As was the case for all other DCWP research, this work was done with data obtained from the NAIC in late 2011.

[13] In the remainder of the text when we refer to 'company' or 'companies' we mean companies or DCWP-defined pools, as appropriate.

[14] Because the all-lines data points are constructed from the filtered LOB data points, the all-lines data excludes the LOBs that do not satisfy the Report 6 and 7 filtering tests. The most important LOB exclusions are the exclusion of Minor Lines data points and the exclusion of data points with less than five years of net earned premium by LOB. In future analyses, the effect of those exclusions might be reviewed.

[15] The diversification index for CoMaxLine% Approach is 100% - CoMaxLine%. The diversification index for HHI Approach is 100% – HHI value%. The diversification index for CoMaxLine%-Risk Approach is 100% - CoMaxLine%-Risk. The diversification index for correlation matrix approach is 100% – risk value after diversification/sum of LOB risk charge%s without diversification, as a percentage.

With different diversification metrics, e.g., correlation or HHI, the diversification band might differ. In practice, we find that the diversification metrics produce ranking of companies by diversification level. That is consistent companies.[16] We select the other diversification bands so that 20% of the multi-line company data points are in each diversification band. We call those diversification bands 1 (least diversified multi-line companies) through 5 (most diversified).

2.1 Company Size and Diversification Characteristics of Risk Data

In this section we describe the characteristics of the data by company size and company diversification.

Number of Company-Year Data Points

Tables 2-1A and 2-1B show the number of company-year data points for reserve risk and premium risk, respectively, in each of the thirty company size/diversification cells (using CoMaxLine% Approach to measuring diversification). The cells highlighted in yellow/bold are the largest and most diversified companies.

Table 2-1A
Number of Reserve Data Points by Size and Diversification

Number of Data Points						
Div Band	Size Band					
	A	B	C	D	E	Total
0	3,870	2,801	2,388	1,824	1,005	11,888
1	539	815	812	764	720	3,650
2	536	718	718	769	909	3,650
3	532	659	**763**	**811**	**885**	3,650
4	452	645	**793**	**925**	**835**	3,650
5	101	387	**553**	**934**	**1,674**	3,649
Total	6,030	6,025	6,027	6,027	6,028	30,137

with the findings in DCWP Report 14, showing that the RBC UW Risk Values are similar across a variety of diversification metrics.

[16] For our purpose, "monoline" means zero diversification credit in the Risk Data. This includes companies with one "major line" and, possibly, several Minor Lines, each of which has less than 5% of all-lines NEP. When we apply the correlation matrix approach, monoline incudes a company with two lines that are 100% correlated.

Table 2-1B
Number of Premium Data Points by Size and Diversification

Number of Data Points						
Div Band	**Size Band**					
	A	**B**	**C**	**D**	**E**	**Total**
0	3,442	2,449	1,798	1,291	688	9,668
1	825	843	909	801	462	3,840
2	529	765	969	885	691	3,839
3	549	806	**813**	**904**	**767**	3,839
4	340	665	**778**	**870**	**1,186**	3,839
5	88	244	**506**	**1,022**	**1,979**	3,839
Total	5,773	5,772	5,773	5,773	5,773	28,864

There are approximately 30,000 data points for each of the premium and reserve data sets (30,137 for reserves and 28,864 for premium). Over 1/3 of data points are for monoline entities with zero diversification (11,888 for reserves and 9,668 for premium). That might be viewed as more monoline companies than anticipated, but the observation is consistent with two features of the data. First, our data records are individual companies, but not company-groups.[17] Second, our data records exclude Minor Line[18] data points by LOB. Some of the monoline companies have other lines, but none of those LOBs has more than 5% of the total premium in that company.

In both tables, looking at the diagonal of data records from the left top (Size A/Div 0) to the bottom right (Size E/Div 5), we see that, monoline companies tend to be smaller and the most diversified companies tend to be larger. Nonetheless, large companies (size band E) are represented in all diversification bands. Almost all cells have at least 500 data points.[19]

We see that the largest companies, size band E, tend to be highly diversified (diversification band 5), although, interestingly, for reserves, the second highest number of companies in size band E is in diversification band 0, monoline.

[17] We consolidate data across groups only if the data is affected by pooling, as described in Reports 6 and 7.
[18] A Minor Line data point is a LOB data point for which the LOB premium or initial reserve is 5% or less of the total all-lines premium and initial reserve.
[19] We imply no significance to the value of 500.

Amount of Reserves/Premium

Tables 2-2A and 2-2B below show the Initial Reserve and NEP, respectively, in each of the thirty company size/diversification cells (using CoMaxLine% Approach to measuring diversification).

Table 2-2A
Total Reserves Amount by Size and Diversification Band (In million)

Div Band	Size Band					
	A	B	C	D	E	Total
0	954	6,569	22,267	73,472	794,126	897,388
1	199	1,888	7,620	32,420	651,723	693,850
2	190	1,709	7,168	31,488	790,745	831,300
3	195	1,537	**7,552**	**31,715**	**1,195,729**	1,236,729
4	173	1,490	**7,829**	**36,229**	**875,078**	920,800
5	40	964	**5,507**	**41,119**	**3,054,924**	3,102,554
Total	1,751	14,159	57,943	246,444	7,362,325	7,682,622

Table 2-2B
Total Premium Amount by Size and Diversification Band (In million)

NEP (millions)						
Div Band	Size Band					
	A	B	C	D	E	Total
0	2,695	10,553	24,752	61,318	277,165	376,482
1	760	3,638	12,783	38,439	273,032	328,652
2	507	3,381	14,147	44,073	393,702	455,810
3	527	3,420	**12,069**	**45,378**	**1,175,892**	1,237,285
4	386	2,843	**11,237**	**44,369**	**1,656,501**	1,715,337
5	114	1,115	**7,405**	**55,777**	**2,293,232**	2,357,643
Total	4,989	24,950	82,393	289,355	6,069,523	6,471,209

These two tables show that most of the reserves and premium come from size band E that has $7.4 trillion[20] of reserves, representing 96% of the total reserves, and $6.1 trillion of premium, representing 94% of total premium. Within this company size band, diversification band 5 has the most reserves ($3.1 trillion) and premium ($2.3 trillion), over 35% of total reserves and premium.

The yellow/bold cells mark the larger/more diversified companies. Table 2-2A shows these represent $5.3 trillion, representing 68% of all reserves. Looking back at Table 2-1A, we see that the yellow/bold cells have 8,173 data points. This is about 27% of all companies, and

[20] The amounts seem large because they represent the sum of reserve amounts at year for each of 22 years of reserve data. The reserve at December 2009 alone was $492 Billion.

slightly over 50% of multiline companies (diversification band >0) with size greater than the smallest 20% (size bands B-E).

The yellow/bold cells in Table 2-2B include $5.3 trillion of premium, representing 82% of all premiums. Looking back at Table 2-1B, we can see that the yellow/bold cells have 8,825 data points, about 31% of the total and slightly over 50% of multiline companies (diversification bands 1-5) with size greater than the smallest 20% (size bands B-E).

Average Reserve/Premium

Tables 2-3A and 2-3B below show the average reserve and average premium amounts by size and diversification band. The average reserve amount in Table 2-3A is the reserve amount in Table 2-2A divided by the number of data points in Table 2-1A. The average premium amount in Table 2-3B is the value in Table 2-2B divided by the number of data points in Table 2-1B.

As expected, size band E has the largest average reserve or premium size and size A has the lowest. The size range between companies is large. For example, the ratio of the average size for the largest size band divided by the average size for the smallest size band is a factor of over 4,000 for reserves ($0.3 million to $1.2 billion) and over 1,000 for premium.[21]

Table 2-3A
Average Reserves Amount by Size and Diversification Band (In million)

Average Reserve Volume by NAIC Band (millions)						
Div Band	Size Band					
	A	B	C	D	E	Total
0	0.2	2.3	9.3	40.3	790.2	75.5
1	0.4	2.3	9.4	42.4	905.2	190.1
2	0.4	2.4	10.0	40.9	869.9	227.8
3	0.4	2.3	**9.9**	**39.1**	**1,351.1**	338.8
4	0.4	2.3	**9.9**	**39.2**	**1,048.0**	252.3
5	0.4	2.5	**10.0**	**44.0**	**1,824.9**	850.2
Total	0.3	2.3	9.6	40.9	1,221.4	254.9

[21] Some of the companies in the data set may be small enough that state regulations might exempt them from making RBC filings. We do not adjust our analysis to reflect that situation.

Table 2-3B
Average Premium Amount by Size and Diversification Band (In million)

Average Premium Volume by NAIC Band (millions)						
Div Band	**Size Band**					
	A	**B**	**C**	**D**	**E**	**Total**
0	0.8	4.3	13.8	47.5	402.9	38.9
1	0.9	4.3	14.1	48.0	591.0	85.6
2	1.0	4.4	14.6	49.8	569.8	118.7
3	1.0	4.2	14.8	50.2	1,533.1	322.3
4	1.1	4.3	14.4	51.0	1,396.7	446.8
5	1.3	4.6	14.6	54.6	1,158.8	614.1
Total	0.9	4.3	14.3	50.1	1,051.4	224.2

Amount of Diversification Credit

Tables 2-4A and 2-4B below show the dollar amount of diversification credit by company size and diversification band. The dollar amount of diversification credit is the difference between the all-lines risk charge with no diversification credit and the all-lines risk charge after diversification credit, based on the 2010 risk factors and the diversification formula in the 2010 RBC Formula.

Following the RBC Formula, there is zero diversification credit for companies in diversification band 0. The amount of diversification credit is small for the smaller companies, size bands A and B. That is partly because the companies in those size bands are somewhat less diversified. [22] It is more so the case because smaller companies have lower reserve /premium amounts , and therefore the diversification amount is smaller, regardless of degree of diversification.

The companies in the yellow/bold cells contain about 94% of the total dollar amount of diversification credit for both reserves and premium.

[22] Table 3-18 shows the diversification as a percentage of the UW Risk RBC Value prior to diversification.

Table 2-4A
Total Reserve Diversification by Company Size and Diversification Band (In million)

Dollar of Diversification Credit - 2010 Reserve Risk Factors						
Div Band	Size Band					
	A	B	C	D	E	Total
0	-	-	-	-	-	-
1	1	9	35	173	3,491	3,709
2	3	26	116	538	16,132	16,815
3	5	43	**220**	**965**	**49,376**	50,609
4	7	58	**346**	**1,647**	**48,019**	50,077
5	2	54	**320**	**2,434**	**204,658**	207,469
Total	18	189	1,038	5,757	321,676	328,679

Table 2-4B
Total Premium Diversification by Company Size and Diversification Band (In million)

Diversification Credit - 2010 Premium Risk Factors						
Div Band	Size Band					
	A	B	C	D	E	Total
0	-	-	-	-	-	-
1	9	50	176	613	3,757	4,606
2	14	97	395	1,301	11,118	12,925
3	20	137	470	1,858	39,438	41,923
4	18	139	536	2,181	74,966	77,838
5	7	66	426	3,320	147,419	151,237
Total	68	488	2,003	9,272	276,699	288,530

3. Analysis – CoMaxLine% Approach

3.1 RBC Formula - Diversification Rule

The RBC Formula instructions present the details of the R_4 and R_5 calculations.[23] The components of those calculations and the simplifications we use in our diversification analysis

[23] Also, for a detailed description of the operation of the RBC Formula, see Odomirok, et al, Chapter 19, Risk Based Capital https://www.casact.org/library/studynotes/Odomirok-etal_Financial-Reportingv4.pdf
For an older description of the Formula and its original basis, see Feldblum, Sholom, NAIC Property/Casualty Insurance Company Risk-Based Capital Requirements, Proceedings of the Casualty Actuarial Society, 1996. http://www.casact.org/pubs/proceed/proceed96/96297.pdf.
For the actual Formula, see NAIC, Risk-Based Capital Forecasting & Instructions, Property Casualty, 2010.

are as follows:

Reserve Risk (R_4)

For each company, for each of the 19 LOBs[24] used in the RBC Formula, the reserve risk value depends on the following, which vary by LOB: the loss and loss adjustment expense reserve net of reinsurance (Initial Reserve) at the valuation date (Initial Reserve Date), the Reserve Risk Factor (RRF) applied to all companies, an adjustment for the difference between company reserve development experience and industry reserve development experience (own-company adjustment), an adjustment for investment income, and a credit for loss sensitive business. The sum of the LOB results is reduced by a diversification credit based on the Loss Concentration Factor (LCF), increased for larger than normal growth and increased by a portion of reinsurance credit risk.

We refer to the ratio of the reserve risk value to the Initial Reserve as the reserve risk charge percentage (RRC%).

Premium Risk (R_5)

For each company, for each of the 19 LOBs[25] used in the RBC Formula, the premium risk value depends on the following, which vary by LOB: the written premium for the latest year net of reinsurance (NWP), the Premium Risk Factor (PRF) applied to all companies, the own-company adjustment, an adjustment for investment income, and a credit for loss sensitive business. The total is combined with the company all lines expenses, reduced by a diversification credit based on the Premium Concentration Factor (PCF), and increased for larger than normal growth.

We refer to the ratio of the premium risk value to the net written premium as the premium risk charge percentage (PRC%).

Simplifications

Our calculations include certain simplifications.

For both reserve risk and premium risk, we do not include the own-company adjustment factor, the loss sensitive business adjustment factor or the growth charge. This is as if the own-

[24] RBC UW risk values are determined using data in the Annual Statement Schedule P, which shows 22 LOBs. RBC calculations treat occurrence and claims made LOBs for other liability and products liability on a combined basis and treat non-proportional property and non-proportional financial on a combined basis, leaving a net of 19 LOBs.

[25] RBC UW risk values are determined using data in the Annual Statement Schedule P, which shows 22 LOBs. RBC calculations treat occurrence and claims made LOBs for other liability and products liability on a combined basis and treat non-proportional property and non-proportional financial on a combined basis, leaving a net of 19 LOBs.

company adjustment and loss sensitive factors were 1.0 and as if the growth risk charge was 0%. We do not include the investment income offset, assuming that the diversification effect is the same before or after the investment income effects.

For premium risk, we use Net Earned Premium (NEP) rather than net written premium. For company expenses in the premium risk calculation, we use the average of the 2010 industry average expense ratio by LOB, weighted by the company specific premium by LOB.[26]

For reserve risk, reserve amounts do not include reserves for adjusting and other expenses. We also do not include the R_3-reinsurance credit risk component for R_4.

In this work, we assume our simplifications do not materially affect our findings.[27]

Determine the Diversification Credit

R_4 and R_5 are first calculated by line of business (LOB). The all-lines R_4, the reserve risk charge, is the sum of the R_4 risk charges by LOB, multiplied by a Loss Concentration Factor (LCF). The all-lines R_5, the premium risk charge, is the sum of the R_5 risk charges by LOB, multiplied by a Premium Concentration Factor (PCF).[28] Using the CoMaxLine% Approach, for each company, the PCF and LCF are determined as follows:

CoMaxLine% for reserves = Initial reserve for the LOB with the largest Initial Reserve divided by the total all-lines Initial Reserve.

CoMaxLine% for premium = NEP[29] for the LOB with the largest premium divided by the total all-lines NEP.

$LCF_{COMPANY} = 0.7 + 0.3 * (CoMaxLine\% \text{ (reserves)}_{COMPANY})$

$PCF_{COMPANY} = 0.7 + 0.3 * (CoMaxLine\% \text{ (premium)}_{COMPANY})$

These can also be written as:

$LCF_{COMPANY} = 100\% - 0.3 * (100\% - CoMaxLine\%_{\text{reserve}})$

$PCF_{COMPANY} = 100\% - 0.3 * (100\% - CoMaxLine\%_{\text{premium}})$

Therefore, the diversification credit equals 30% times (100%-CoMaxLine%) where the

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[26] We make this simplification because expenses by LOB for all years in our data set were not readily available to us.

[27] Further research will be necessary to verify that assumption.

[28] The LCF and PCF are applied to the sum of the LOB RBC amounts, where those RBC amounts reflect the investment income offset, the own-company experience adjustment, and the loss sensitive business adjustment.

[29] NWP in the RBC Formula. NEP in our simplified calculation.

diversification index is (100%-CoMaxLine%)

LOB risk factors

The observed diversification relationship might depend on the selection of LOB risk factors. Therefore, in our analysis, we do not use the LOB PRFs and RRFs in the 2010 RBC Formula. Instead, we use the LOB PRFs and RRFs indicated by the reserve and premium risk data that we use in this diversification analysis. By using these indicated risk factors, we avoid possible distortions resulting from use of LOB risk factors that are not consistent with the data we use for the diversification analysis. In Appendix 1/Exhibit 1, we show the 2010 LOB risk factors and the LOB risk factors that we use in this analysis.

3.2 Analysis Method

In our analysis, we examine the data by size band and diversification band. For each of the size/diversification cells, we calculate the following:

1. Observed Risk – For reserves, this is the 87.5th percentile[30] all-lines RRR. For premium, this is the 87.5th percentile all-lines AY Underwriting Gain/Loss percentage (AYUL in dollars and AYUL%, as a percentage of premium).

   The AYUL% by company equals the company all lines average loss ratio plus the all lines company expense ratio[31] minus 100%.
2. Expected Risk – This is the average RBC Formula result, including or excluding the diversification credit, as needed, for premium and reserves separately, averaged across companies.

   We express the expected risk as a ratio to reserves, for reserve risk, and as a ratio to premium, for premium risk. We refer to those ratios as the expected reserve risk charge% and expected premium risk charge%, respectively, and expected risk charge% generically.

   In using the RBC Formula to measured expected risk, we treat the RBC Formula as the model that predicts the RRR or AYUL% at the 87.5th percentile risk level.

   In Appendix 1/Exhibits 2-3 we show an example of how we use the risk data to calculate the all-lines expected risk charge%, the diversification band and size band for

[30] We use the 87.5th percentile because that is the safety level last used (2016) in the calibration of LOB risk factors. The diversification relationship might be different if the safety level were the 90th percentile or some other value. Evaluating the variation in indicated diversification credit with changing safety level is a matter for future research.

[31] As noted in the "Simplifications" subsection above, for company expense we use industry expenses by LOB, weighted by the company NEP by LOB.

a sample company/year risk data point, for reserve risk and premium risk, respectively.

3. We vary the MDC (30% in the RBC Formula) to improve the 'fit' between the observed risk and the expected risk based on the RBC Formula.

In our analysis we examine the data in three levels of detail, as follows:

- A 2 x 2 split of monoline vs. multi-line and smallest size band vs. all other size bands combined.
- A 2 x 6 split treating each of six diversification bands separately and considering two size bands, smallest size band vs. all other size bands combined.
- A 5 x 6 split treating each diversification/size band separately.

With the 2x2 analysis we test the 30% MDC. With the 2x6 analysis we evaluate the extent to which the indicated diversification credit varies linearly with the diversification index, 100%-CoMaxLine%, as well as testing the 30% MDC. The 5x6 analysis adds more insight into the extent to which differences in experience among company sizes B, C, D and E affect the observed pattern for sizes B-E combined, used in the 2x6 analysis.

3.3 Diversification– 2x2 Analysis

In this section, we examine the data in 4 company size/diversification cells:

- By company size band– split the companies by size into the smallest 20% of companies and the other 80%, and
- By company diversification band - split the companies into two diversification bands: monoline companies and multiline companies.

3.3.1 Observed vs. Expected Effect of Diversification

Expected Risk Charge%s

Table 3-1, below, shows the all-lines expected reserve and expected premium risk charge%s based on the CoMaxLine% Approach, with the 30% MDC, for each of the cells in the 2x2 array by company size and company diversification.

Table 3-1
Expected Risk Charge%

Div Band	Reserves Size Band		Premium Size Band	
	<20%	**>=20%**	**<20%**	**>=20%**
0	34.1%	32.7%	27.8%	29.3%
>0	28.7%	**30.7%**	22.4%	**21.8%**

Note: Expected risk charge% is from application of the RBC Formula Value, with the 30% MDC.
Appendix 1/Exhibits 2 and 3 show how one company-year of data enters the calculation in Table 3-1, for reserve risk and premium risk respectively.

The expected risk charge% in each cell of Table 3-1 is the unweighted average of the company-year risk charge%s from the RBC Formula for companies in that cell, i.e., the risk data points are equally weighted, regardless of company reserves/premium amount.

<u>Observed Risk</u>

Table 3-2, below, shows the 87.5th percentile RRR and the 87.5th percentile AYUL% for all company-years in the size/diversification cell. These are the indicated all-lines reserve and all-lines premium risk charge%s corresponding to the expected risk charge%s in Table 3-1.

Table 3-2
Indicated Risk Charge

Div Band	Reserves Size Band		Premium Size Band	
	<20%	>=20%	<20%	>=20%
0	63.0%	26.5%	56.2%	28.7%
>0	54.7%	**27.2%**	43.9%	**17.8%**

Appendix 1/Exhibits 2 and 3 show how one company-year of data enters the calculation in Table 3-2, for reserve risk and premium risk respectively.

<u>Comments on comparison of expected to observed risk charges/Tables 3-1 and 3-2</u>

Focus on Multi-Line Companies/Company size Excluding Smallest 20% of Companies

In comparing observed risk charge%s to expected risk charge%s, we focus on the yellow/bold cells because:

- Diversification band 0, monoline companies, provides no information about the benefit of diversification, as there is none, [32] and
- The small company data in column <20% is not useful in a diversification

[32] Also, see Section 4 and Appendix 2 for further discussion of the extent to which LOB indicated risk charge%s vary by company level of diversification.

calibration, as the risk charge%s for LOBs at that size are not consistent with the risk charge%s for the bulk of the companies that have larger sizes.[33]

The Indicated MDC is Greater than 30%

If the CoMaxLine% Approach, and all other features of the RBC Formula were "perfect," then the expected values, Table 3-1, would equal the corresponding value in the array of observed values, Table 3-2, at least on average. Looking at the yellow/bold cells, that, is not the case. The observed risk charge%s are lower than the expected risk charge%s, so a MDC greater than 30% is indicated.[34]

For example, for reserves, in the yellow/bold cell, the expected risk charge% is 30.7%. The indicated risk charge% is 27.2%. As 27.2% is less than 30.7%, the data indicates that the 30% MDC is not giving enough diversification credit for reserve risk, for multi-line companies larger than the smallest 20%.

Similarly, for premium, in the yellow/bold cell, the expected risk charge% is 21.8%. The indicated risk charge% is 17.8%. As 17.8% is less than 21.8%, the data indicates that the 30% MDC is not giving enough diversification credit for premium risk, for multi-line companies larger than the smallest 20%.

3.3.2 Indicated MDC

To determine the indicated MDC, we use Tables 3-1 and 3-2, above, and Tables 3-3 through 3-5 below.

Table 3-3, below, shows the all-lines expected risk charge% based on the RBC Formula with no diversification credit. As required by the operation of the RBC Formula, the values in Table 3-3 equal the values in Table 3-1 for the 0 diversification band, and the values in Table 3-3 are higher than the values in Table 3-1 for the >0 diversification band.

[33] For similar reasons, our calibration of indicated risk charge%s by LOB in DCWP Reports 6 and 7 uses data excluding the smallest 15% of LOB data points. In those reports we observe that the indicated risk charge%s for small LOB-sizes are much higher than the risk charge%s for larger LOB-sizes that constitute the bulk of the number of companies and premium and reserve amounts. As the RBC Formula does not allow different rick charges % by LOB-size. Reports 6 and 7, and the American Academy of Actuaries analysis of risk changes, exclude experience of the smallest companies in determined risk charge%s. As small LOB-sizes will predominate in smaller companies, excluding the smallest companies from the dependency analysis is the all-lines analogue of the LOB-size strategy with respect to LOB risk charge% caligba5tion.

[34] The only parameter in the diversification element in the RBC Formula is the MDC, and for this analysis we take all other features of the RBC Formula as fixed.

Table 3-3
Expected Risk Charge% Before Diversification

Div Band	Reserves		Premium	
	Size Band		Size Band	
	<20%	>=20%	<20%	>=20%
0	34.1%	32.7%	27.8%	29.3%
>0	31.2%	**34.2%**	24.8%	**25.0%**

Note: Expected risk charge% before diversification is the RBC Formula Value before applying LCF/PCF.

Table 3-4, below, shows current average diversification credit, i.e., the value based on the CoMaxLine% Approach and the 30% MDC for reserve and premium risk values.[35]

Table 3-4
Current Average Diversification Credit with RBC Formula and 30% MDC

Div Band	Reserves		Premium	
	Size Band		Size Band	
	<20%	>=20%	<20%	>=20%
0	0.0%	0.0%	0.0%	0.0%
>0	7.7%	**9.9%**	9.8%	**13.3%**

As required by the operation of the RBC Formula, the values in Table 3-4 equal zero for the diversification band 0. The value 9.9% for reserves, diversification >0 and size >=20% is the average diversification credit for companies in that size/diversification cell, and the corresponding average CoMaxLine% for those companies is 67.1%.[36]

Based on Tables 3-1 to 3-4, above, we calculate the indicated MDC in Table 3-5, below. The calculation uses the data for multiline companies, excluding the smallest 20% of companies, i.e., yellow/bold cells in Tables 3-1 to 3-4, for the reasons described in Section 3.3.1 above.

[35] This is the unweighted average of the company-year diversification credits for companies in that cell, i.e., the risk data points are equally weighted, regardless of company reserves/premium amount.
[36] LCF = 1- diversification credit = 90.1%. 90.1% = 0.7 + .3 * .671.

Table 3-5
Overall Indicated MDC (2x2 Analysis)

	(1)	(2)	(3)
#	**Item**	**Reserves**	**Premium**
1	Observed Risk - 87.5th RRR/AYUL (Table 3-2)	27.2%	17.8%
2	Expected Risk – Apply RBC Formula before diversification (Table 3-3)	34.2%	25.0%
3	Indicated Diversification Credit 1.0-(1)/(2)%	20.6%	28.8%
4	Average Diversification Credit (Current Formula) (Table 3-4)	9.9%	13.3%
5	Indicated Maximum Credit [(3)/(4) * 30%]	62%	65%

The elements of the calculation in Table 3-5 are as follows:

- Row 1 - The observed risk, 87.5th percentile all-lines AYUL% and RRR. This is 27.2% for reserve risk, and 17.8% for premium risk (From Table 3-2).
- Row 2 – The expected risk, the all-lines reserve and premium risk charge%s calculated with from the RBC Formula, before considering the diversification adjustment. This is the average, all companies equally weighted, of the LOB premium or reserves risk charge%s, before diversification credits (From Table 3-3).
- Row 3 –The indicated average diversification credit, 1.0- (1)/ (2), expressed as a percentage. This is the diversification credit that, if applied on average, all companies equally weighted, would result in expected reserve and premium risk charge%s equal to observed risk reserve and premium risk charges.
- Row 4 - The current average diversification credit, the unweighted average, i.e., all companies equally weighted, of the value "30% * (100%-CoMaxLine%)," across all company-years in this analysis. (From Table 3-4)
  The Row 3 value is more than the Row 4 value showing that the indicated credit diversification is greater than the credit produced by the RBC Formula.
- Row 5 – The indicated MDC, Row (5) = Row (3)/Row (4) * 30%. The indicated MDC is 65% for premium and 62% for reserves.[37]

Thus, Table 3-5 shows that, based on 2x2 analysis, the indicated diversification formulas are:

LCF = 38% plus 62% * CoMaxLine%

[37] Given the structure of the RBC Formula, the only parameter that can be adjusted is the MDC.

PCF = 35% plus 65% * CoMaxLine%

The values 65% and 62% are more than twice the current value of 30%, driven by the fact that the indicated diversification (20.6% and 28.8%, line 3, for reserves and premiums, respectively) are more than twice the current average diversification (9.9% and 13.3%, line 4, for reserves and premiums, respectively).

This indicated MDC reflects risk theory diversification effects and the extent to which indicated LOB risk charge%s vary by degree of diversification. We describe the latter effect in Section 4 and in Appendix 2. Regardless of the causes, Row 5 is an estimate of the MDC that is indicated by the risk data, using the selected PRFs/RRFs, given the structure of the RBC Formula.

3.4 Diversification - 2x6 Analysis (Two Size Bands/Six Diversification Bands)

In this section, we examine the data in 12 cells, as follows:

- By company size – split the companies by size into the smallest 20% and the other 80%, 2 size bands, and
- By company diversification band - split the companies by diversification into one monoline band and five multiline bands, 6 diversification bands in total.

In this 2x6 analysis we can test both the MDC and the extent to which the diversification credit is linear with CoMaxLine%. In Section 3.3, above, with less diversification segmentation, we only tested the value of the MDC. Our analysis, in sections 3.4.1 and 3.4.2 below, follows the approach described in sections 3.3.1 and 3.3.2 for the 2x2 analysis.

3.4.1 Observed vs. Expected Effect of Diversification Experience

Table 3-6, below, shows the all-lines expected reserve and premium risk charge%s based on the CoMaxLine% Approach with the 30% MDC, for each of the cells in the 2x6 array by company size and company diversification. Table 3-6 is a more detailed segmentation of Table 3-1.

Table 3-6
Expected Risk Charge%

Div Band	Reserves Size Band <20%	Reserves Size Band >=20%	Premium Size Band <20%	Premium Size Band >=20%
0	34.1%	32.7%	27.8%	29.3%
1	27.4%	30.0%	25.3%	28.0%
2	28.9%	29.6%	23.4%	22.3%
3	28.6%	**31.3%**	20.0%	**20.9%**
4	29.6%	**32.0%**	18.9%	**19.9%**
5	29.8%	**30.5%**	19.1%	**18.9%**
all x 0	28.7%	30.7%	22.4%	21.8%

Note: Expected risk charge% is the RBC Formula Value, including 30% MDC.

Table 3-7, below, shows the 87.5th percentile RRR and the 87.5th percentile AYUL%. These are the indicated all-lines reserve and premium risk charge%s corresponding to the expected risk charge%s in Table 3-6. Table 3-7 is a more detailed segmentation of Table 3-2. The rows 0 and all x 0 in Table 3-7 have the same values as the corresponding rows, 0 and >0 in Table 3-2.

Table 3-7
Indicated Risk Charge

Div Band	Reserves Size Band <20%	Reserves Size Band >=20%	Premium Size Band <20%	Premium Size Band >=20%
0	63.0%	26.5%	56.2%	28.7%
1	53.4%	26.7%	44.7%	24.4%
2	54.0%	26.9%	42.1%	16.5%
3	74.6%	**28.2%**	44.1%	**18.0%**
4	44.9%	**28.5%**	32.8%	**16.7%**
5	36.5%	**25.6%**	55.9%	**16.0%**
all x 0	54.7%	27.2%	43.9%	17.8%

3.4.2 Indicated MDC

To determine the indicated diversification credit with this 2x6 data segmentation, we use Tables 3-6 and 3-7, above, plus the information in Tables 3-8 to 3-11 below. The analysis is analogous to the Table 3-5 calculation in section 3.3 for the 2x2 array of data:

- Table 3-8 - Expected Risk Charge% Before Diversification Credit (analogous to Table 3-3)

- Table 3-9 - Indicated Average Diversification Credit (analogous to Table 3-5 line 3, but not shown as separate Table in section 3.3).
  These values equal 100% - Table 3-7/Table 3-8.
- Table 3-10 - Current Average Diversification Credit (analogous to Table 3-4)
- Table 3-11 - Indicated MDC (analogous to Table 3-5)
  These values equal 30% * Table 3-9/Table 3-10.

Table 3-8

Expected Risk Charge% Before Diversification

Div Band	Reserves		Premium	
	Size Band		Size Band	
	<20%	>=20%	<20%	>=20%
0	34.1%	32.7%	27.8%	29.3%
1	27.9%	30.5%	26.3%	29.2%
2	30.6%	31.3%	25.7%	24.7%
3	31.6%	**34.6%**	23.0%	**24.1%**
4	34.2%	**36.9%**	22.5%	**23.9%**
5	36.0%	**37.2%**	23.9%	**23.8%**
all x 0	31.2%	34.2%	24.8%	25.0%

Note: Expected risk charge% Before Diversification is the RBC Formula Value before applying the LCF/PCF.

Table 3-9

Indicated Average Diversification Credit

Div Band	Reserves		Premium	
	Size Band		Size Band	
	<20%	>=20%	<20%	>=20%
0	-84.7%	18.8%	-102.0%	1.9%
1	-91.3%	12.4%	-69.5%	16.5%
2	-76.5%	14.2%	-63.4%	33.1%
3	-135.8%	**18.4%**	-91.8%	**25.3%**
4	-31.3%	**22.7%**	-45.8%	**30.1%**
5	-1.6%	**31.2%**	-133.5%	**33.0%**
all x 0	-75.3%	20.6%	-77.3%	28.8%

Table 3-10
Current Average Diversification Credit with RBC Formula and 30% MDC

Div Band	Reserves		Premium	
	Size Band		Size Band	
	<20%	>=20%	<20%	>=20%
0	0.0%	0.0%	0.0%	0.0%
1	1.8%	1.7%	4.1%	4.3%
2	5.5%	5.4%	9.4%	9.5%
3	9.4%	**9.5%**	13.2%	**13.3%**
4	13.4%	**13.4%**	16.2%	**16.5%**
5	17.2%	**18.1%**	20.0%	**20.8%**
all x 0	7.7%	9.9%	9.8%	13.3%

Table 3-11
Indicated MDC

Div Band	Reserves		Premium	
	Size Band		Size Band	
	<20%	>=20%	<20%	>=20%
0	NA	NA	NA	NA
1	-1524.0%	211.9%	-513.5%	114.1%
2	-417.5%	78.2%	-203.2%	104.0%
3	-431.7%	**58.4%**	-208.9%	**57.3%**
4	-70.3%	**51.0%**	-84.6%	**54.7%**
5	-2.7%	**51.7%**	-200.3%	**47.6%**
all x 0	-291.9%	62.5%	-236.8%	64.9%

For calibration, we focus on the cells in yellow/bold because:

- Diversification band 0, monoline companies, provide no information about the benefit of diversification, as there is none.
- The small company data in column <20% is not useful in diversification calibration of as the risk charge%s for LOBs at that size are not consistent with the risk charge%s for the bulk of the companies that have reserve/premium larger sizes and the bulk of the diversification credit. [38]
- Those cells represent the overwhelming proportion of diversification credit, as shown in Table 2-4A and 2-4B.
- Moreover, the diversification bands "1" and "2" show high values for the indicated

[38] See footnote 33.

MDC, compared to the indicated MDC for diversification bands 3-5.

In Appendix 2 we show that, for diversification bands 1 and 2, the indicated LOB risk factors are different from the indicated LOB risk factors for diversification bands 3-5. Thus, the high indications for diversification levels 1 and 2 are not relevant for calibrating diversification for the companies in diversification bands 3-5 that constitute the bulk of premium and reserves amounts and the overwhelming proportion of industry total diversification credit.

For these yellow/bold cells, Table 3-11 shows that the indicated MDC is almost always more than 50%.[39]

3.4.3 Testing Linear Relationship between CoMaxLine% and Indicated Diversification Credit

Next, we use regression through the origin to test the validity of the linear relationship between indicated diversification credit and 100%-CoMaxLine% and to further test the indicated diversification credit. We use regression through the origin because a diversification formula must give zero credit when there is zero diversification. The dependent variable is the indicated average diversification credit (Table 3-9). The independent variable is the diversification index, "100% - CoMaxLine%," (Table 3-10 divided by 30%).[40] We exclude the smallest 20% of companies from this analysis, for the reasons discussed above.

Table 3-12, below, presents the regression results. [41]

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[39] Note that the typical indicated MDC in the yellow/bold cells of Table 3-10 is 50%. This is lower than the 60+% indicated MDC from Table 3-5. Looking at Table 3-11, we see that the highest indicated values for the indicated MDC are in diversification bands 1 and 2 with indicated MDC values from 75% to over 200%. Thus, the 2x6 analysis enables us to calibrate the diversification credit using the experience of companies in diversification bands 3-5, that represent the bulk of reserves, premiums and diversification credit, with no distortion from the indications for bands 1 and 2.

[40] We graph the values divided, by 30%, rather than the Table 3-10 values, so that the slope of graph is the indicated MDC.

[41] The R-squared statistics on Table 3-12 are calculated by Excel regression in Excel data pack. The Excel formula for R-squared for regression through the origin is not the same as the R-squared formula used for OLS regression. Joseph G Eisenhauer (2003), Teaching Statistics, 25(3), 76-80. We use this form of the R-squared statistic to compare regression results, given the 'through the origin' constraint.

Table 3-12
Regression Analysis of Diversification Formula

Div Band	Reserves			Premium		
	1	2	3	4	5	6
	Average Div Index	Indicated Div Credit	Fitted Div Credit	Average Div Index	Indicated Div Credit	Fitted Div Credit
0	0.0%	18.8%	0.0%	0.0%	1.9%	0.0%
1	5.8%	12.4%	3.2%	14.5%	16.5%	8.3%
2	18.1%	14.2%	9.9%	31.8%	33.1%	18.4%
3	31.5%	18.4%	17.2%	44.2%	25.3%	25.5%
4	44.5%	22.7%	24.2%	55.0%	30.1%	31.7%
5	60.5%	31.2%	32.9%	69.4%	33.0%	40.1%
	Slope		54%	Slope		58%
	R-square		82%	R-square		92%

Columns 1 and 4 equal Table 3-10 divided by .30. We use the diversification index rather than the average diversification credit, for simplicity, so that the slope equals the indicated MDC.
Columns 2 and 5 from Table 3-9.
Data excludes company size band A, the 20% smallest companies.
The regression includes data from diversification band 0. If we exclude diversification band 0 and recalculate the regression, the slope is not affected but the R-squared values are 95% and 92% for reserve and premium respectively.

Table 3-13 shows the regression results graphically. Table 3-13 shows that the linear relationship through the origin is particularly close for the three data points representing the largest/most diversified companies.

Based on those results, the indicated diversification formulas are:

LCF = 46% plus 54% * CoMaxLine%

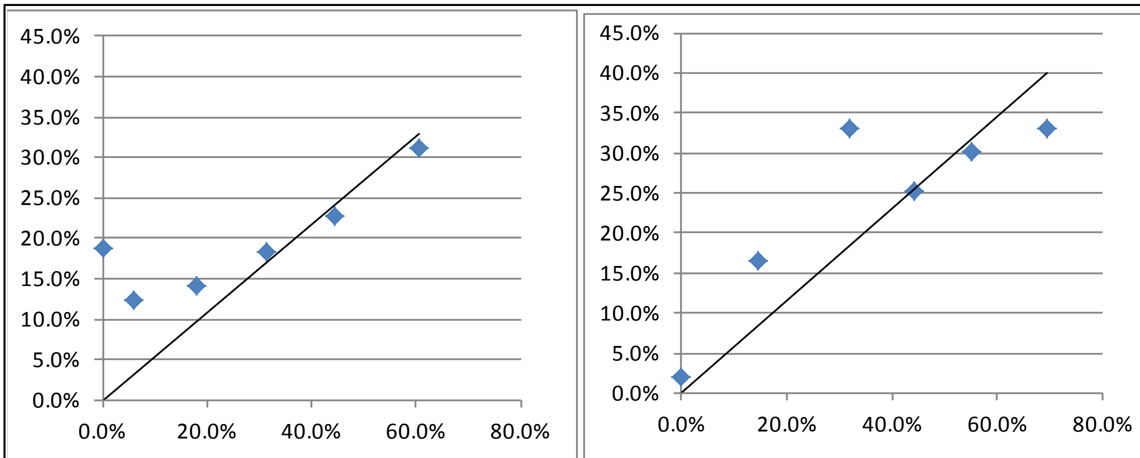
PCF = 42% plus 58% * CoMaxLine%

The regression lines show that, for reserves, every 100-basis point increase in the diversification index will result in a 54-basis point increase in the indicated diversification credit. For premium, every 100-basis point increase in the diversification index will result in a 58 basis point increases in the indicated diversification credit.

These formulas provide larger diversification credits than the current 30% MDC, over 50%, but less than the parameters from the 2x2 analysis.

Table 3-13
Regression Results

Reserves		**Premium**	



Slope	54%	Slope	58%
R-Square	82%	R-Square	92%

X-Axis shows 100% - CoMaxLine% that equals Average Diversification Credit /0.3.
Y-Axis shows indicated diversification credit.

3.5 Diversification - 5x6 Analysis (Five Size Bands /Six Diversification Bands

In this section, we examine the data in 30 cells,

- By company size – split the companies into 5 size bands, and
- By company diversification - split the companies into 6 diversification bands

We follow the same approach as in the 2x2 and 2x6 analyses in Sections 3.3 and 3.4 respectively. We show that the findings from section 3.4, the 2x6 analysis, remain valid.

3.5.1 Observed vs. Expected Effect of Diversification Experience

Table 3-14, below, shows the all-lines expected reserve and premium risk charge%s based on the CoMaxLine% Approach with the 30% MDC, for each cell in the 5x6 array by company size and company diversification.[42] This analysis is analogous to the analysis shown in Tables 3-1 and 3-6.

[42] Table 3-14 is a more detailed segmentation of Table 3-1 and Table 3-6.

Table 3-14
Expected Risk Charge%

Diversif. Band Quintiles	Reserves					Premium				
	Size Band (Quintiles)					Size Band (Quintiles)				
	A	B	C	D	E	A	B	C	D	E
0	34.1%	33.9%	33.0%	31.1%	31.3%	27.8%	28.5%	28.9%	31.1%	30.0%
1	27.4%	28.0%	30.9%	32.4%	28.6%	25.3%	26.4%	26.4%	30.3%	30.2%
2	28.9%	29.2%	29.6%	30.4%	29.2%	23.4%	22.9%	21.6%	21.8%	23.5%
3	28.6%	29.2%	**30.4%**	**30.2%**	**34.7%**	20.0%	21.2%	**20.2%**	**20.5%**	**22.0%**
4	29.6%	28.7%	**31.6%**	**31.8%**	**34.9%**	18.9%	20.0%	**19.4%**	**20.0%**	**20.1%**
5	29.8%	29.4%	**30.0%**	**29.7%**	**31.3%**	19.1%	18.8%	**18.2%**	**18.4%**	**19.3%**
All Ex 0	28.7%	28.8%	30.6%	30.9%	31.8%	22.4%	22.5%	21.6%	21.9%	21.4%

Note: Expected risk charge% is the RBC Formula Value, including 30% MDC.

Table 3-15, below, shows the 87.5th percentile RRR and the 87.5th percentile AYUL%. These are the indicated all-lines reserve and premium risk charge%s corresponding to expected risk charge%s in Table 3-13.[43] This analysis is analogous to the analysis shown in Tables 3-2 and 3-7.

Table 3-15
Indicated Risk charge%

Diversif. Band Quintiles	Reserves					Premium				
	Size Band (Quintiles)					Size Band (Quintiles)				
	A	B	C	D	E	A	B	C	D	E
0	63.0%	38.2%	25.1%	21.2%	18.2%	56.2%	29.0%	25.9%	27.2%	36.6%
1	53.4%	33.6%	27.2%	29.9%	15.1%	44.7%	20.8%	25.1%	21.8%	38.5%
2	54.0%	34.7%	29.7%	28.7%	17.0%	42.1%	19.4%	15.2%	16.5%	15.0%
3	74.6%	39.4%	**27.0%**	**22.2%**	**25.2%**	44.1%	20.7%	**17.2%**	**17.9%**	**16.6%**
4	44.9%	36.3%	**31.9%**	**22.5%**	**28.8%**	32.8%	13.7%	**18.1%**	**18.2%**	**15.7%**
5	36.5%	30.5%	**24.1%**	**23.6%**	**25.6%**	55.9%	22.0%	**15.4%**	**16.4%**	**15.3%**
All Ex 0	54.7%	35.2%	27.9%	25.1%	23.7%	43.9%	19.3%	18.2%	17.8%	16.8%

3.5.2 Indicated MDC

To examine the indicated diversification credit, we use Table 3-14 and 3-15, above, and the information in Tables 3-16 to 3-19 below. The analysis is analogous to that used in section 3.3.2, for the 2x2 analysis, and section 3.4.2, for the 2x6 analysis:

- Table 3-16 - Expected risk charge% before diversification credit (analogous to Tables 3-8 and 3-3)
- Table 3-17 - Indicated Average Diversification Credit (analogous to Tables 3-9 and 3-5 line 3). These are 100% - Table 3-15/Table 3-14

[43] Table 3-15 is a more detailed segmentation of Table 3-2 and Table 3-7.

- Table 3-18 - Current Average Diversification Credit (analogous to Tables 3-10 and 3-4)
- Table 3-19 - Indicated MDC (analogous to Tables 3-11 and 3-5)
  This is 30% times Table 3-17 / Table 3-18.

Table 3-16
Expected Risk Charge% Before Diversification

Diversif. Band Quintiles	Reserves Size Band (Quintiles)					Premium Size Band (Quintiles)				
	A	B	C	D	E	A	B	C	D	E
0	34.1%	33.9%	33.0%	31.1%	31.3%	27.8%	28.5%	28.9%	31.1%	30.0%
1	27.9%	28.5%	31.4%	32.9%	29.1%	26.3%	27.6%	27.6%	31.6%	31.5%
2	30.6%	30.9%	31.3%	32.1%	30.9%	25.7%	25.3%	23.9%	24.1%	26.0%
3	31.6%	32.2%	**33.6%**	**33.4%**	**38.4%**	23.0%	24.4%	**23.3%**	**23.6%**	**25.4%**
4	34.2%	33.2%	**36.5%**	**36.7%**	**40.3%**	22.5%	23.9%	**23.2%**	**24.0%**	**24.1%**
5	36.0%	35.6%	**36.5%**	**36.2%**	**38.4%**	23.9%	23.5%	**22.9%**	**23.2%**	**24.5%**
All Ex 0	31.2%	31.6%	33.7%	34.4%	36.0%	24.8%	25.3%	24.3%	25.1%	25.4%

Note: Expected risk charge% Before Diversification is the RBC Formula Value before applying the LCF/PCF.

Table 3-17
Indicated Average Diversification Credit

Diversif. Band Quintiles	Reserves Size Band (Quintiles)					Premium Size Band (Quintiles)				
	A	B	C	D	E	A	B	C	D	E
0	-84.7%	-12.6%	24.0%	31.8%	41.8%	-102.0%	-1.7%	10.4%	12.5%	-22.0%
1	-91.3%	-18.0%	13.5%	9.1%	48.2%	-69.5%	24.5%	9.0%	31.0%	-22.3%
2	-76.5%	-12.5%	5.0%	10.7%	45.0%	-63.4%	23.2%	36.6%	31.6%	42.1%
3	-135.8%	-22.4%	**19.5%**	**33.7%**	**34.2%**	-91.8%	15.4%	**26.1%**	**24.2%**	**34.7%**
4	-31.3%	-9.3%	**12.8%**	**38.8%**	**28.5%**	-45.8%	42.8%	**21.9%**	**24.1%**	**35.0%**
5	-1.6%	14.4%	**33.9%**	**34.8%**	**33.5%**	-133.5%	6.4%	**32.7%**	**29.3%**	**37.4%**
All Ex 0	-75.3%	-11.5%	17.4%	27.0%	34.3%	-77.3%	23.6%	25.4%	29.2%	33.7%

Table 3-18
Current Average Diversification Credit with RBC Formula and 30% MDC

Diversif. Band Quintiles	Reserves					`				
	Size Band (Quintiles)					Size Band (Quintiles)				
	A	B	C	D	E	A	B	C	D	E
0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1	1.8%	1.7%	1.6%	1.7%	2.0%	4.1%	4.4%	4.4%	4.3%	4.2%
2	5.5%	5.4%	5.5%	5.4%	5.4%	9.4%	9.5%	9.5%	9.6%	9.6%
3	9.4%	9.4%	**9.4%**	**9.6%**	**9.4%**	13.2%	13.2%	**13.3%**	**13.2%**	**13.3%**
4	13.4%	13.3%	**13.3%**	**13.4%**	**13.4%**	16.2%	16.3%	**16.5%**	**16.6%**	**16.6%**
5	17.2%	17.4%	**17.8%**	**18.0%**	**18.5%**	20.0%	20.2%	**20.2%**	**20.5%**	**21.2%**
All Ex 0	7.7%	8.3%	9.0%	10.1%	11.3%	9.8%	11.3%	11.8%	13.2%	15.8%

Table 3-19
Indicated MDC

Diversif. Band Quintiles	Reserves					Premium				
	Size Band (Quintiles)					Size Band (Quintiles)				
	A	B	C	D	E	A	B	C	D	E
0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	-1524.0%	-310.2%	247.1%	165.0%	731.8%	-513.5%	167.1%	61.4%	218.5%	-159.0%
2	-417.5%	-69.6%	27.3%	59.1%	248.8%	-203.2%	73.4%	115.6%	98.9%	131.1%
3	-431.7%	-71.6%	**61.9%**	**105.7%**	**108.8%**	-208.9%	35.0%	**58.9%**	**54.9%**	**78.1%**
4	-70.3%	-20.9%	**28.7%**	**87.0%**	**64.0%**	-84.6%	78.8%	**39.9%**	**43.7%**	**63.3%**
5	-2.7%	24.8%	**57.2%**	**58.0%**	**54.3%**	-200.3%	9.6%	**48.5%**	**42.8%**	**52.9%**
All Ex 0	-291.9%	-41.5%	57.7%	80.3%	91.0%	-236.8%	62.9%	64.3%	66.3%	63.9%

We focus on data cells highlighted in yellow/bold, for the reasons we discuss in Section 3.4.2. Those yellow/bold cells in Table 3-19 show indicated MDCs that average over 50% for reserve and premium risk charges. This is consistent with the findings from Table 3-11, the 2x6 analysis.

3.5.3 Testing Linear Relationship between CoMaxLine% and Indicated Diversification Credit

Next, we use regression through the origin to further test both the indicated MDC and to test the validity of the linear relationship between 100%-CoMaxLine% and the indicated diversification credit. The dependent variable is the indicated average diversification credit (Table 3-17). The independent variable is 100% - CoMaxLine% (Table 3-18 divided by 30%).

Table 3-20A, below, presents the regression results showing that the indicated MDC, the value of the slope, is approximately 50%, although with lower R-square[44] values than in the

[44] The R-squared statistic is calculated by Excel regression in Excel data pack. The Excel formula for R-squared for regression through the origin is not the same as the R-squared formula used for OLS regression. Joseph G Eisenhauer (2003), Teaching Statistics, 25(3), 76-80.

2x6 analysis. For reserves, for every 100-basis point increase in the diversification index will result in 48 basis point increases in the diversification credit. For premium, for every 100-basis point increase in the diversification index will result in 54 basis point increases in the diversification credit.

Table 3-20A
Regression Analysis of Diversification Formula
Excluding Smallest Companies and Monoline Companies

Div Band	Size Band	Reserves			Premium		
		1	2	3	4	5	6
		Average Div Level	Indicated Div Credit	Fitted Div Credit	Average Div Level	Indicated Div Credit	Fitted Div Credit
1	B	5.8%	-18.0%	2.8%	14.7%	24.5%	7.9%
1	C	5.5%	13.5%	2.6%	14.7%	9.0%	7.9%
1	D	5.5%	9.1%	2.6%	14.2%	31.0%	7.7%
1	E	6.6%	48.2%	3.1%	14.0%	-22.3%	7.6%
2	B	18.0%	-12.5%	8.6%	31.6%	23.2%	17.0%
2	C	18.2%	5.0%	8.7%	31.6%	36.6%	17.0%
2	D	18.2%	10.7%	8.7%	32.0%	31.6%	17.2%
2	E	18.1%	45.0%	8.6%	32.1%	42.1%	17.3%
3	B	31.3%	-22.4%	14.9%	44.1%	15.4%	23.8%
3	C	31.5%	19.5%	15.0%	44.2%	26.1%	23.8%
3	D	31.9%	33.7%	15.2%	44.0%	24.2%	23.7%
3	E	31.4%	34.2%	15.0%	44.5%	34.7%	24.0%
4	B	44.5%	-9.3%	21.2%	54.3%	42.8%	29.3%
4	C	44.5%	12.8%	21.2%	54.9%	21.9%	29.6%
4	D	44.6%	38.8%	21.3%	55.2%	24.1%	29.7%
4	E	44.6%	28.5%	21.3%	55.3%	35.0%	29.8%
5	B	57.9%	14.4%	27.6%	67.2%	6.4%	36.2%
5	C	59.3%	33.9%	28.3%	67.5%	32.7%	36.3%
5	D	59.9%	34.8%	28.6%	68.4%	29.3%	36.9%
5	E	61.7%	33.5%	29.4%	70.7%	37.4%	38.1%
		Slope		48%	Slope		54%
		R-square		40%	R-square		72%

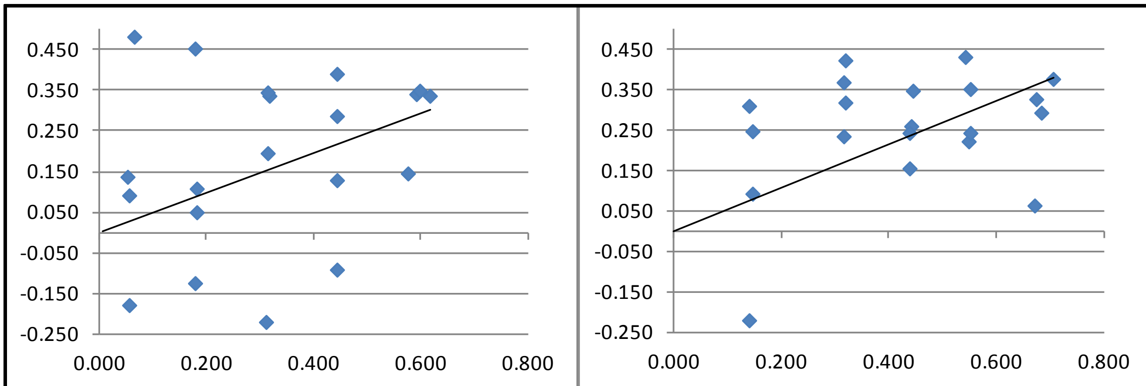
Columns 1 and 4 equal the values in Table 3-18/30%.
Columns 2 and 5 from Table 3-17.
Column 3 is based on regression through the origin.
The R-squared values based on regression through the origin.[45]

Table 3-20B shows the fitted diversion credit regression results graphically.

[45] The R-squared statistic is calculated by Excel regression in Excel data pack. The Excel formula for R-squared for regression through the origin is not the same as the R-squared formula used for OLS regression. Joseph G Eisenhauer (2003), Teaching Statistics, 25(3), 76-80.

Table 3-20B
Table 3-20A Graphically

Reserves **Premium**



	Reserves		Premium
Slope	48%	Slope	54%
R-Square	40%	R-Square	72%

X-Axis shows 100% - CoMaxLine% (Average Diversification Credit /0.3).
Y-Axis shows indicated diversification factor.
Line is the fitted diversion credit in Table 3-21A
Line is extrapolated back to origin, zero diversification implying zero diversification credit.

Tables 3-21A and 3-21B, below, show the same information as 3-20A and 3-20B, above, for the nine data points, C3 to E5, which represent the largest and most diversified companies that constitute the bulk of the reserve, premium and diversification credit amounts. The nine-point regressions in Tables 3-21A and 3-21B have a much higher R-square value than the 20-point regressions in Tables 3-20A and 3-20B. Based on the 9-point regression, for reserves, every 100-basis point increase in the diversification index will result in a 63 basis point increases in the diversification credit. For premium, every 100-basis point increase in diversification index will result in a 52 basis point increases in the diversification credit.

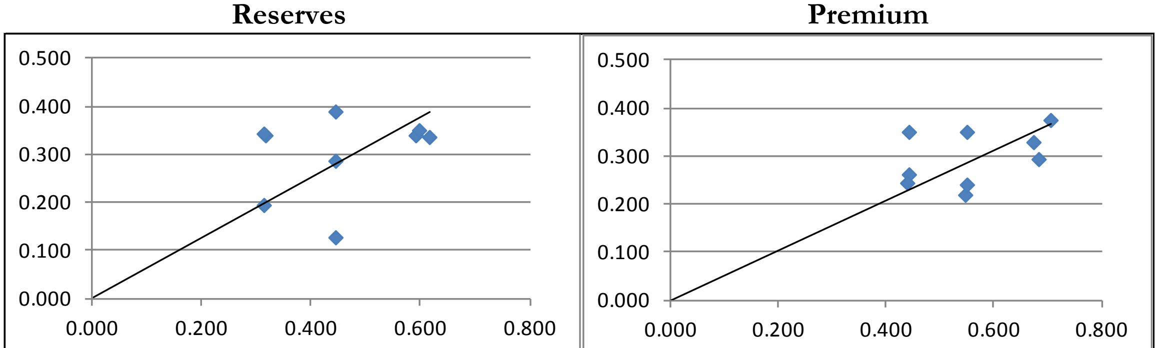
Table 3-21A
Regression Analysis of Diversification Formula All (Large and Diversified Only)
Size Band B-E/Diversification Bands 3-5

Div Band	Size Band	Reserves			Premium		
		1	2	3	4	5	6
		Average Div Level	Indicated Div Credit	Fitted Div Credit	Average Div Level	Indicated Div Credit	Fitted Div Credit
C	3	31.5%	19.5%	19.8%	44.2%	26.1%	22.8%
D	3	31.9%	33.7%	20.1%	44.0%	24.2%	22.7%
E	3	31.4%	34.2%	19.8%	44.5%	34.7%	23.0%
C	4	44.5%	12.8%	28.0%	54.9%	21.9%	28.3%
D	4	44.6%	38.8%	28.0%	55.2%	24.1%	28.5%
E	4	44.6%	28.5%	28.0%	55.3%	35.0%	28.5%
C	5	59.3%	33.9%	37.3%	67.5%	32.7%	34.8%
D	5	59.9%	34.8%	37.7%	68.4%	29.3%	35.3%
E	5	61.7%	33.5%	38.8%	70.7%	37.4%	36.5%
		Slope		63%	Slope		52%
		R-square		91%	R-square		96%

Columns 1-6 from selected rows of Table 3-20A
The R-squared values based on regression through the origin.[46]

Table 3-21B
Table 3-21A Graphically

Reserves **Premium**



Slope	63%	Slope	52%
R-Square	91%	R-Square	96%

X-Axis shows 100% - CoMaxLine%, or, equivalently Average Diversification Credit /0.3.
Y-Axis shows indicated diversification factor.
Line is the fitted diversion credit in Table 3-21A
Line is extrapolated back to origin, zero diversification implying zero diversification credit.

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[46] The R-squared statistic is calculated by Excel regression in Excel data pack. The Excel formula for R-squared for regression through the origin is not the same as the R-squared formula used for OLS regression. Joseph G Eisenhauer (2003), Teaching Statistics, 25(3), 76-80. We use this form of the R-squared statistic to compare regression results, given the 'through the origin' constraint.

Based on those results, the indicated diversification formulas are:

LCF = 37% plus 63% * CoMaxLine%

PCF = 48% plus 52% * CoMaxLine%

4. Alternative Diversification Approaches

In this section we test alternatives to the CoMaxLine% Approach.

4.1 Alternatives to CoMaxLine%

From the risk theory perspective, the natural approach to diversification is to combine risk charges by LOB using correlation factors between each pair of LOBs. Individual company capital models often use this pairwise correlation approach. The Solvency II Standard Formula uses the pairwise correlation approach. The correlation approach, if applied in the RBC Formula, uses 171 parameters.[47] In contrast to the correlation approach, the RBC Formula CoMaxLine% Approach might be described as 'simple," perhaps too simple, and ad hoc.

One difference between the CoMaxLine% Approach and the correlation matrix approach, as normally applied, is that the degree of diversification in the correlation matrix approach is based on risk by LOB while the degree of diversification in the CoMaxLine% Approach is based on volume (premium amount or reserve amount) by LOB. Therefore, another alternative to CoMaxLine% and correlation matrix approaches, is the CoMaxLine%-Risk Approach, in which we apply the CoMaxLine% Approach to LOB risk rather than LOB volume, when calculating the LCF and PCF for a company.

Another alternative to the CoMaxLine% and the correlation matrix approach is the HHI approach, used by economists to measure concentration. HHI considers the relative proportions of all LOBs, the largest, second largest, third largest, and so on.[48] This is simpler than the correlation approach, but it is more complex than the CoMaxLine% Approach in

[47] One parameter for each pair of LOBs, i.e., 19 LOBs each need to be paired with the 18 other LOBs, thus 19x18 = 342, divided by 2 because the relationship be LOB "X" and LOB "Y" is the same as the relationship between LOB "Y" and LOB "X". Therefore, in theory that requires 171 parameters. In practice Solvency II uses 2 parameters, 25% and 50%, and judgement to decide whether each of 171 LOB pairs is lower correlation (25%) or higher correlation (50%).

[48] HHI equals the sum of the squares of the LOB shares of total. For example, if there is only one LOB, HHI is 1.0, as is the case for CoMaxLine%. With two lines split 25% and 75% HHI is 0.25 ^2 plus 0.75^2 or 0.625 compared the CoMaxLine% of 0.750, i.e., it shows less concentration/more diversification. With three lines split 50%, 25% and 25% HHI is 0.50^2 plus 0.25^2 plus 0.25^2 or 0.375, less concentration/more diversification than the CoMaxLine% of 0.5.

that the HHI approach recognizes the extent of diversification for the 2nd, 3rd, 4th, etc. largest LOBs.[49]

Any of these approaches to diversification is an approximation. The theoretical requirements for risk theory diversification approach do not fully apply to standard formulas, at least as evidenced by our risk data, for reasons that include the following:

1. LOB charges vary not only by LOB, but within LOBs based on the degree of specialization of the insurer, extent of reinsurance usage, etc.
   For example, with our risk data, the indicated personal automobile risk charge% for a monoline, or near monoline, company is not the same as the indicated risk charge% for personal lines automobile for multi-line companies.[50] Appendix 2 shows our analysis of variation in LOB risk charge% by variation in company diversification.
2. The LOB risk charge%s and, possibly, diversification parameters, might vary by LOB-size. The differences by LOB-size are not part of either the RBC or the Solvency II Standard Formula. As such, the LOB risk charges and the correlations relationships are, at best, correct for a particular set of LOB-sizes and/or on average across all LOB-sizes.
3. For the most plausible LOB-size distributions, the "normal-family" assumption underlying the covariance formula might not be satisfied.[51]

In addition to those three issues, which affect the theoretical framework, as a practical matter there may not be enough data for all the potential parameters. For the correlation matrix approach, even the DCWP database, with 30,000 company/year/all-line data points (for each of the premium and reserve data sets),[52] may not be adequate to support a data-driven calibration of the 171 required diversification parameters, especially if differences in the diversification relationship by company size are reflected.

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[49] The HHI is sometimes applied to only the n-th largest segments, e.g., the degree of diversification among the top ten LOBs. The HHI index applied to the single largest segment would be very similar to the CoMaxLine%. HHI can be written as p_1^2 + p_2^2+p_3^2…p_n^2. The truncated HHI limited to one element would be p_1^2. CoMaxLine% is p_1.

[50] This feature of the data implies that a key assumption in the risk theory diversification framework not valid. In mathematical terms, the risk distribution by LOB f(x) should be the same regardless of the proportion of business from line of business y. We find that f(x|no other business) ≠ f(x| there is some other business); f(x|(company has enough y to be at Diversification level 1), ≠ f(x|(company has enough y to be at Diversification level 2), ≠ f(x|(company has enough y to be at Diversification level 2), etc.

[51] This issue might be addressed using copulas, but that requires further parameterization.

[52] To our knowledge, this database is larger than any other database used for Standard Formula calibrations.

4.2 Analysis of Alternatives

To apply the correlation approach for our testing, we first construct a set of pairwise correlation factors, called a correlation matrix. Following the Solvency II approach, we construct the correlation matrix using values of 25% or 50%[53] for most of the 171 LOB-pairs. For several LOB-pairs that we consider very highly correlated we select correlation factors of 75% or 100%.[54] Appendix 3/Exhibit 1 shows the Solvency II correlation matrix for the 12 Solvency II non-life LOBs. Appendix 3/Exhibit 2 shows the correlation matrix that we use.

Then, for each of the four diversification approaches, i.e., the CoMaxLine% Approach, the correlation matrix approach, the CoMaxLine%-risk approach and the HHI approach, we compare the indicated risk charge%s to the formula risk charge%s for each of the thirty company-size/diversification band cells, separately for premium risk and reserve risk. Appendix 4 shows the calculations of indicated risk charge%s and differences between the indicated risk charge%s and the risk charge%s from the RBC Formula with the CoMaxLine% and correlation matrix dependency formulas.[55]

In Table 4-1, below, we summarize the 30 indicated versus formula results, for CoMaxLine% Approach and correlation matrix approach, from Part 5 of Appendix 4. We use three measures of indicated versus formula differences. We refer to those as 'error statistics' for each method. These error statistics are as follows:

- Standard deviation,
- Average error, and
- Average absolute error

We calculate the error statistics for each of the following three sets of points by company size/diversification band, separately for reserves and premium:

- All Points – All, excluding monoline companies (25 size/diversification segments)
- Exclude the smallest – All, other than the smallest company sizes and monoline companies, i.e., across company size/diversification bands B1-E5 (20

[53] "Advice for Band 2 Implementing Measures on Solvency II: SCR Standard Formula Article 111(d) Correlations," (former Consultation Paper 74), January 2010, pp 39-44. See Appendix 3 of this paper for further discussion of the origin of the Solvency II correlation matrix.

[54] We select pairwise correlations of 100% for claims made and occurrence medical malpractice and for general liability, special liability and products liability. We select pairwise correlations of 75% between special property and homeowners, between private passenger automobile liability and automobile physical damage and between commercial automobile liability and automobile physical damage.

[55] The analysis for the HHI and CoMaxLine%-Risk are analogous to those in Appendix 4, for CoMaxLine% and correlation matrix. We do not present the HHI or CoMaxLine%-Risk details in this Report.

size/diversification segments).

- Include only the largest/most diversified - The largest, most diversified companies that constitute the bulk of the reserves/premiums and diversification credit, i.e., company size/diversification bands C3-E5 (9 size/diversification segments).

Table 4-1, below, shows that, for reserves, the correlation approach has somewhat lower error statistics. For example, the correlation matrix approach has the lowest error statistic for 8 of the 8 tests[56], and the lowest error statistic for the 9-point test that represents the bulk of the reserves, premium and diversification credit. For premium, Table 4-1 shows that the CoMaxLine% Approach (labeled NAIC) often has somewhat lower error statistics. For example, the CoMaxLine% Approach has the lowest error statistic for 7 of the 8 tests, and the lowest error statistic for the 9-point test that represents the bulk of the reserves, premium and diversification credit.

Overall, we conclude that the correlation approach does not better represent the data than the CoMaxLine% Approach.

[56] There are eight tests, rather than nine. The value for "Include only largest (9 points)" for Average Error is always zero because we select the best fitting risk charge%s to achieve that result.
By a "lower error score" we mean the absolute value of the difference between indicated and expected has a smaller absolute value.

Table 4-1
Error Statistics – CoMaxLine% (NAIC) vs. Correlation Matrix (Correlation) Approaches
Error Measured as % of Reserves/Premium
Multi-Line Companies Only
[Green Highlight indicates the lower value within each pair of models]

Standard Deviations				
	Reserves		Premium	
Points Included	**NAIC**	**Correlation**	**NAIC**	**Correlation**
All Points (25 points)	0.13	0.11	0.11	0.12
Exclude Smallest (20 points)	0.07	0.06	0.040	0.038
Include only Largest (9 points)	0.03	0.02	0.01	0.02

Average Error				
	Reserves		Premium	
Points Included	**NAIC**	**Correlation**	**NAIC**	**Correlation**
All Points (25 points)	6.5%	4.7%	4.4%	4.3%
Exclude Smallest (20 points)	1.2%	0.7%	-0.7%	-1.2%
Include only Largest (9 points)	0%	0.0%	0%	0%

Absolute Average Error				
	Reserves		Premium	
Points Included	**NAIC**	**Correlation**	**NAIC**	**Correlation**
All Points (25 points)	9.7%	8.0%	7.4%	7.7%
Exclude Smallest (20 points)	5.3%	4.9%	3.0%	3.1%
Include only Largest (9 points)	2.9%	1.9%	1.1%	1.5%

Green highlight indicates whether NAIC (CoMaxLine%) or Correlation Matrix approaches provide the lower error within each group of cells. Data rounded to show differences.
Note – For "Average Error" section, the overall level is set so that the average error equals zero for the largest 9 points.
We express the error statistics as a percentage of reserves/premium. Risk charge%s are approximately 20% of reserves/premium, so a 1% error premium is a 5% error in the risk charge. Thus 1% is a small, but not negligible proportion of the risk charge.

Table 4-2, below, shows the same error statistics but for all four of the methods for reserve risk and premium risk.[57]

[57] The analysis for the HHI and CoMaxLine%-Risk are analogous to those in Appendix 4, for CoMaxLine% and correlation matrix. We do not present the HHI or CoMaxLine%-Risk details in this Report.

Table 4-2
Error Statistics – CoMaxLine% (NAIC) vs. CoMaxLine%-Risk Approach
Error Measured as % of Reserves/Premium
[Green Highlight indicates the lowest value among the four models]

A. Standard Deviations

	Reserves				Premium			
Points Included	**NAIC**	**Correlation**	**HHI**	**CoMaxLine % - Risk**	**NAIC**	**Correlation**	**HHI**	**CoMaxLine % - Risk**
All Points (25 points)	0.133	0.120	0.168	0.126	0.114	0.128	0.125	0.105
Exclude Smallest (20 points)	0.067	0.063	0.050	0.066	0.040	0.038	0.037	0.031
Include only Largest (9 points)	0.035	0.023	0.026	0.028	0.014	0.021	0.014	0.010

B. Average Error

	Reserves				Premium			
Points Included	**NAIC**	**Correlation**	**HHI**	**CoMaxLine % - Risk**	**NAIC**	**Correlation**	**HHI**	**CoMaxLine % - Risk**
All Points (25 points)	6.5%	5.6%	9.6%	5.7%	4.37%	4.43%	5.8%	3.5%
Exclude Smallest (20 points)	1.2%	0.8%	3.3%	1.1%	-0.7%	-1.2%	0.2%	-1.4%
Include only Largest (9 points)	0%	0%	0%	0%	0.0%	0.0%	0%	0.0%

C. Absolute Average Error

	Reserves				Premium			
Points Included	**NAIC**	**Correlation**	**HHI**	**CoMaxLine % - Risk**	**NAIC**	**Correlation**	**HHI**	**CoMaxLine % - Risk**
All Points (25 points)	9.7%	8.9%	10.5%	9.3%	7.4%	7.8%	7.7%	6.7%
Exclude Smallest (20 points)	5.3%	4.9%	4.4%	5.2%	3.0%	3.1%	2.5%	2.6%
Include only Largest (9 points)	2.9%	1.9%	2.1%	2.3%	1.1%	1.6%	1.1%	0.9%

Green highlight indicates whether NAIC (CoMaxLine%), correlation matrix, HHI or CoMaxLine%-Risk approaches provides the lower error within each group of cells. Data rounded to show differences.
Note – For "Average Error" section, the overall level is set so that the average error equals zero for the largest 9 points.
We express the error statistics as a percentage of reserves/premium. Risk charge%s are approximately 20% of reserves/premium, so a 1% error premium is a 5% error in the risk charge. Thus 1% is a small, but not negligible proportion of the risk charge.

In this 4-way comparison, we see that:

- The RBC CoMaxLine% Approach does not have the lowest error statistics for any size group for either premium or reserves; however,
- As we saw in Table 4-1, comparing CoMaxLine% and correlation matrix approaches, CoMaxLine% has lower error statistics premium while correlation matrix approach has lower error statistics for reserves.
- CoMaxLine%-Risk has lower error statistics than CoMaxLine% for both premium and reserves (8 of 8 for reserves and 7 of 8 for premium and, in particular, for the two 9-point tests). For premium, CoMaxLine%-Risk has the lowest error statistics across the four approaches.
- The difference between the RBC Approach and the method with the lowest error

statistics is always less than 1.7% of reserves/premium (therefore less than about 10% of average UW risk RBC).

LOB Risk Factors that vary by LOB-size

In Appendix 5, we address the extent to which our findings regarding diversification with CoMaxLine% Approach would be affected if the RBC Formula used risk factors that vary by LOB-size.

This question is motivated, in part, because we observe that LOB-size, company-size and diversification level are inter-related. For example, we observe that larger LOB-sizes indicate risk charge%s that are lower than the risk charges%s indicated by smaller LOB-sizes. Therefore, it could be the case higher indicated diversification credits are a proxy for lower LOB risk charge%s for larger companies.

We test that hypothesis by applying LOB risk charge%s that vary by LOB-size. We find that the indicated MDC would be different if the risk factors were determined by LOB size, we find that the indicated MDC% is greater than 30% and our conclusion regarding CoMaxLine% versus correlation matrix remains the same.[58]

5. Overall Findings

Thus, we find that:

- The linear relationship between diversification discount and 100%-CoMaxLine%, in the CoMaxLine% Approach is not perfect, but it is a reasonable approximation, especially close for the most diversified companies.
- A MDC of at least 50% is better supported by the data than the current 30% MDC.
- The CoMaxLine%-Risk Approach may be better than the CoMaxLine% Approach.
- Neither the correlation matrix approach nor the HHI approach represents the data significantly better than the diversification approach in the RBC Formula for both reserve risk and premium risk.

6. Future Research

Our analysis uses certain simplifications. The expected risk charge%s in our analysis do not include the effect of Investment Income Offset (IIO), loss sensitive business, own-company adjustment or growth risk in the expected risk charges. To convert premium risk factors to

[58] We did not test the comparison for HHI or CoMaxLine% risk.

AYUL and AYUL% we use industry-total expense by LOB, adjusted to the company LOB distribution, rather than company-by-company expenses. Our analysis uses risk data that satisfies the LOB filtering tests, described in DCWP Reports 6 and 7, and therefore does not include Minor Lines data points or other data points removed for LOB risk factor analysis. We do not include the R_3-Reinsurance Credit Risk Element of R_4. Future research could test the extent to which, if at all, those simplifications affect the indicated MDC or the conclusion regarding the extent to which there is a linear relationship between diversification and CoMaxLine%.

We did not evaluate the HHI-Risk approach, analogous to CoMaxLine%-Risk, in which HHI is applied to amount of risk rather than amount of reserve/premium. Also, the RBC formula might consider both diversification by LOB and diversification among types of multi-line companies, e.g., personal vs. standard commercial vs. specialty. Future research could test the extent to which those approaches better reflect observed diversification patterns.

Future research could evaluate the extent to which there might be improvements to the error statistics we used to compare the alternative diversification formulas.

Our analysis is based on a target safety level of 87.5%. Future research could examine the extent to the conclusions vary if a different safety level were selected.

7. Glossary

Annual Statement	US NAIC Annual Statement
CoMaxLine%	The NAIC measure of concentration, the percentage of a company's total premium or reserves from its single largest LOB.
CoMaxLine% Approach	The NAIC method of determining diversification credit. The diversification credit is (1.0 – CoMaxLine%) times 30%.
CoMaxLine%-Risk Approach	CoMaxLine% Approach based on risk charge value by LOB rather than premium or reserve volume by LOB.
Correlation approach	We use that term to characterize methods of combining LOB risk charges to produce an all-lines risk charge using 'correlation factors.' Our use of the term does not imply that the assumptions underlying individual and joint distributions of the parameters are satisfied.
Correlation Factor	A factor used to express the relationship between individual risks to produce the risk parameter of interest for the combined risk. Our use of the term does not imply that the assumptions underlying individual and joint distributions of the parameters are satisfied.
Correlation Matrix	A matrix array of correlation factors, with one factor for each pair of LOBs.
DCWP	Risk-Based Capital Dependency and Calibration Working Party of the Casualty Actuarial Society
Initial Reserve	The reserve amount at the Initial Reserve Date for all accident years prior to the Initial Reserve Date.
Initial Reserve Date	December 31st for the year specified (i.e., December 31, 2010 is the Initial Reserve Date for the 2010 net loss reserve which includes AY's 2010 and prior)
LCF	Loss (Reserve) Concentration Factor as calculated in 2010 RBC Formula. Based on CoMaxLine% Approach.
LOB	Schedule P Lines of Business used in the RBC Formula. Note that three pairs of Schedule P LOBs are combined; occurrence and claims Other Liability (Line H), occurrence and claims made Products Liability (Line R), and Reinsurance: nonproportional property and Reinsurance: nonproportional financial (Lines P and N, respectively).
Loss sensitive business adjustment	An element of the RBC Formula that reduces the risk charge if unfavorable experience can be offset by increases in revenue on loss sensitive business.
MDC	Maximum Diversification Credit, 30% in the 2010 RBC Formula
NAIC	National Association of Insurance Commissioners
Own-company adjustment, or 50/50 rule	RBC premium and reserve factors are based 50% on factors calibrated based on industry data and 50% based on the industry data adjusted by the ratio of company experience to industry experience. (Subject to certain exceptions.)

PCF	Premium Concentration Factor as calculated in 2010 RBC Formula. Based on CoMaxLine% Approach.
R_0	Insurance affiliate investment and (non-derivative) off-balance sheet risk.
R_1	Asset Risk – Fixed Income Investments
R_2	Asset Risk – Equity
R_3	Credit risk (non-reinsurance plus one half of Reinsurance Credit Risk)[56]
R_3-Reinsurance Credit Risk	See Reinsurance Credit Risk
R_4	Reserve risk plus one half of R_3-reinsurance credit risk.[59] This paper uses R_4 without R_3-reinsurance credit risk.
R_5	Premium risk.
RBC	Risk-Based Capital
RBC Formula or Formula	The 2010 NAIC Property-Casualty RBC Formula
RBC UW Risk Value	The Company Action Level amount calculated for the UW risk components of the RBC Formula for a company or DCWP defined group of companies.
Reinsurance Credit Risk	An element of R_3, representing both credit risks related to reinsurance counterparty and the difference in premium and reserve risk of between companies with varying levels of ceded reinsurance.
Reserves or Loss Reserves	Case, bulk and IBNR loss and defense and cost containment expense[60] reserves net of reinsurance, as shown in Schedule P – Part 2 and 3.
Schedule P	A set of exhibits in the Annual Statement that provide most of the risk data used in our analysis.
Solvency II	EU regulation and related implementing measures
Standard Formula	A formula determining capital requirements under Solvency II, RBC or other regulatory capital systems
UW	Underwriting
UW risk	Underwriting risk – the combination of premium risk and reserve risk

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[59] The 'transfer' from credit risk to reserve risk applies only if the reserve risk without the reinsurance credit risk component is larger than the reinsurance credit risk, as is most often the case.

[60] "Defense and Cost Containment Expenses" are called "Allocated Loss Adjustment Expenses" in older Annual Statements. In our analysis we treat defense and cost containment expense and allocated loss adjustment expenses as equivalent.

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Appendix 1- Indicated Risk Factors and Sample Calculations

Appendix 1/Exhibit 1
Indicated PRC% and RRC% by LOB

Line of Business	2010 PRFs/RRFs		Indicated PRFs/RRFs for Dependency Analysis			
	(1)	(2)	(3)	(4)	(5)	(6)
	PRF	RRF	PRF	CER	PRC%	RRF
A- Homeowners/Farmowners	0.937	0.201	0.956	0.301	0.257	0.225
B- Private Passenger Auto	0.969	0.192	0.969	0.252	0.221	0.179
C- Commercial Auto	0.988	0.230	0.988	0.308	0.296	0.352
D - Workers Compensation	1.033	0.324	1.039	0.268	0.307	0.333
E - Commercial Multi-Peril	0.921	0.465	0.879	0.355	0.234	0.488
F1 - Med Prof Liab-Occ	1.822	0.431	1.458	0.280	0.738	0.306
F2 - Med Prof Liab-CM	1.092	0.306	1.146	0.280	0.426	0.106
G - Special Liability	0.904	0.257	0.947	0.344	0.291	0.455
H - Other Liability	1.042	0.511	1.015	0.303	0.318	0.525
I - Special Property	0.941	0.191	0.817	0.326	0.143	0.331
J - Auto Physical Damage	0.843	0.112	0.828	0.252	0.080	0.194
K - Fidelity/Surety	0.883	0.325	0.644	0.454	0.098	0.560
L - Other	0.893	0.172	0.923	0.358	0.281	0.274
M - International	1.169	0.327	0.899	0.400	0.299	0.508
N&P - Reinsurance-Prop/Fin	1.349	0.286	1.288	0.247	0.535	0.422
O - Reinsurance-Liabiity	1.507	0.769	1.302	0.247	0.549	0.650
R - Products Liability	1.214	0.643	1.184	0.311	0.495	0.883
S - Financial/Mort Guarantee	1.482	0.200	0.725	0.285	0.010	0.560
T - Warranty	0.883	0.325	0.879	0.359	0.238	0.488

CER = Company Expense Ratio. Equals 2010 industry average underwriting expense ratio by LOB.
F1 and F2 – same expense ratio;
H is average of H1 and H2; R is average of R1 and R2
Same expense ratio for N&P and O

Risk Data Selection

As described in DCWP Reports 6 and 7, the risk data we use in our calculation of the RRFs/PRFs shown above excludes anomalous values; treats pool company data on a combined basis; excludes Minor Lines data points; and, for premium risk data, excludes companies with less than 5 AYs of NEP. We also exclude the LOB data points for the smallest LOBs, defined as those in the smallest 15th percentile of all LOB-company-year data points, with the 15th percentile determined separately for each AY/Initial Reserve Date.

For premium risk, the data points do not include data for 2001-2010 AYs for companies that did not file a 2010 Annual Statement. For reserve risk, the data points include 2001-2000

Initial Reserve Dates, to the extent such information is in any Annual Statement.

The risk data values are the values at the latest available maturity.

To convert premium risk factors to premium risk charge%s we use 2010 industry-total expense by LOB.

Appendix 1/Exhibit 2
Example of Data Underlying Expected Risk Charge% and Indicated Risk charge%
Calculation for a Sample Company
Reserve Risk Data

(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Modeled Reserve Risk			Observed Reserve Experience		
Line	**Initial Reserve**	**Modeled Risk Charge %**	**Modeled Risk Charge $**	**Observed Reserve Runoff $**	**Observed Reserve Runoff %**	**Reserve % by LOB**
A	6,458	22.5%	1,453	(1,733)	-26.8%	5.2%
B	-	17.9%	-	-	-	
C	25,334	35.2%	8,918	(4,111)	-16.2%	20.4%
D	28,643	33.3%	9,538	1,524	5.3%	23.0%
E	18,091	48.8%	8,828	(4,623)	-25.6%	14.6%
F1	-	30.6%	-	-	-	
F2	-	10.6%	-	-	-	
G	-	45.5%	-	-	-	
H	35,596	52.5%	18,688	(9,834)	-27.6%	28.6%
I	-	33.1%		-	-	
J	-	19.4%	-	-	-	
K	-	56.0%	-	-	-	
L	-	27.4%	-	-	-	
M	-	50.8%	-	-	-	
N_P	-	42.2%	-	-	-	
O	-	65.0%	-	-	-	
R	10,203	88.3%	9,009	4,098	40.2%	8.2%
S	-	56.0%	-	-	-	
T	-	48.8%	-	-	-	
Total/Avg	124,325	45.4%	56,434	(14,679)	-11.8%	100.0%

Diversification Approach	**Diversification Index**
8.CoMaxLine%	71.4%
9.CoMaxLine%-Risk	66.9%
10. HHI	79.3%
11. Correlation Matrix	76.7%

These calculations are described below, in Notes to Appendix 1/Exhibit 2.

Notes to Appendix 1/Exhibit 2

Col/ Row	Notes
Col 1	Line of Business
Col 2	Data – loss and LAE reserve for the sample company-year-line of business
Col 3	Indicated Reserve Risk Factor shown in Appendix 1/Exhibit 1/Column 6
Col 4	(2) x (3)
Col 5	Data – company-year-LOB reserve runoff from Initial Reserve Date through the latest available maturity. Negative values indicate favorable runoff.
Col 6	(5)/ (1) – reserve runoff as a percentage of Initial Reserve;
Col 7	LOB Initial Reserve / all line total Initial Reserve (2)/ All line total (2)
Row 8	100% - Maximum LOB % from column (7)
Row 9	100% - Maximum value in Column 4/Total of Column 4
Row 10	HHI calculation 100% - Sum of squares of percentages in column 7
Row 11	Calculated from correlation matrix in Appendix 3/Exhibit 1 applied to expected risk amounts column 4.

The all-lines risk information in the Total/Avg row provides a single company-year data point used to calculate expected risk and indicated risk. We use the data in Rows 8-11 to categorize each company by diversification band.

Appendix 1/Exhibit 3
Example of Data Underlying Expected Risk Charge% and Indicated Risk charge%
Calculation for a Sample Company
Premium Risk Data

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Expected Premium Risk			**Observed Premium Experience**			
Line	Premium	Expected Risk Charge %	Expected Risk Charge $	Observed Loss Ratio	Industry Expense Ratio	Observed AYUL%	Premium % by LOB
A	14,903	25.7%	3,833	80.5%	30.1%	10.6%	6.9%
B	13,679	22.1%	3,018	89.2%	25.2%	14.4%	6.3%
C	18,591	29.6%	5,512	85.1%	30.8%	15.9%	8.6%
D	22,324	30.7%	6,863	72.9%	26.8%	-0.3%	10.3%
E	20,541	23.4%	4,808	101.7%	35.5%	37.2%	9.5%
F1	-	73.8%	-	-	28.0%	-	-
F2	-	42.6%	-	-	28.0%	-	-
G	-	29.1%	-	-	34.4%	-	-
H	24,492	31.8%	7,800	43.1%	30.3%	-26.6%	11.3%
I	34,772	14.3%	4,960	51.5%	32.6%	-15.9%	16.1%
J	20,933	8.0%	1,684	84.4%	25.2%	9.6%	9.7%
K	16,893	9.8%	1,660	11.8%	45.4%	-42.8%	7.8%
L	-	28.1%	-	-	35.8%	-	-
M	-	29.9%	-	-	40.0%	-	-
N_P	28,979	53.5%	15,504	75.7%	24.7%	0.4%	13.4%
O	-	54.9%	-	-	24.7%	-	-
R	-	49.5%	-	-	31.1%	-	-
S	-	1.0%	-	-	28.5%	-	-
T	-	23.8%	-	-	35.9%	-	-
Total/Avg	216,107	25.7%	55,641	68.1%	30.4%	-1.4%	100.0%

Diversification Approach	Diversification Index
9. CoMaxLine%	83.9%
10.CoMaxLine%-Risk	72.1%
11. HHI	89.2%
12. Correlation Matrix Diversification	64.8%

These calculations are described below, in Notes to Appendix 1/Exhibit 3.

Notes to Appendix 1/Exhibit 3

Col/ Row	Notes
Col 1	Line of Business
Col 2	Data – Net earned premium for the sample company-year-line of business
Col 3	Indicated Premium Risk Charge shown in Appendix 1/Exhibit 1/Column 5
Col 4	(2) x (3)
Col 5	Data – Loss and LAE ratio at the latest available maturity
Col 6	Data – 2010 industry expense ratio. Used as a proxy for company expense ratios as these are not readily available for each year in the experience period.
Col 7	(5)+(6)-100%
Col 8	Line of Business Premium/ all line total Premium; (2)/ All line total (2)
Row 9	100% - Maximum LOB % from column 8
Row 10	100% - Maximum value in Column 4/ Total of column 4
Row 11	HHI calculation 100% - Sum of squares of percentages in column 8
Row 12	Calculated from correlation matrix in Appendix 3/Exhibit 1 applied to expected risk amounts in column 4.

The all-lines risk information in the Total/Avg row provides a single company-year data point used to calculate expected risk and indicated risk. We use the data in Rows 9-12 to categorize each company by diversification band.

Appendix 2 - LOB Risk Charge%s Vary with Degree of Diversification of The Company.

In individual company capital modeling, diversification credit arises because the risk[61] associated with the combined LOB (1 + 2) business is generally less than the sum of LOB 1 risk and LOB 2 risk. The magnitude reduction depends on the extent to which the two LOBs risk characteristics are correlated. Using the correlation relationship (and some statistical assumptions) allows the determination of the LOB (1+2) risk from the separate LOB1 and LOB2 risk. This framework requires that the LOB risk charge%s are independent of the degree of diversification of the company.

In calibrating a Standard Formula, on the other hand, the LOB1 risk charge is based on data for all levels of company diversification combined, i.e., {LOB1|all diversification levels}. This {LOB1|all diversification levels} may not have the same as risk as {LOB1|monoline company} or {LOB1|given that the company writes some of LOB2 and perhaps other LOBs}. Similarly, {LOB2|all diversification levels} may not have the same risk as {LOB2|monoline Company} and {LOB2|given the companies writes some LOB1 and perhaps other LOBs}.

Therefore, the risk for LOB (1+2) (at specific diversification levels) would not necessarily follow from {LOB1|all diversification levels} and {LOB2|all diversification levels}. In fact, our review of the Risk Data we find that there are variations in LOB risk charge%s with the degree of diversification of the company. For some LOBs, for example, for the personal automobile liability LOB, monoline companies[62] have higher PPA LOB risk charge%s than diversified companies. That might follow from reduced geographic risk diversification in monoline companies, or other features of those companies. For other LOBs, e.g., monoline MPL, monoline companies have lower LOB risk charge%s than diversified companies. That might follow from benefits of specialization, the type of policies, e.g., primary vs. excess or physicians vs. hospitals, or other factors.

Regardless of the underlying causes, Appendix 2/Exhibits 1A and 1B, below, show that LOB risk charge%s vary with diversification level of the company. For more than half of the 32 LOBs (16 for each of premium and reserve risk), the indicated PRF/RRF at zero

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[61] As in earlier sections of this paper, we use the term "risk" to mean the 87.5th percentile of the observed distribution. The analysis in this section applies regardless of the percentile safety level and for alternative risk metrics other than VaR

[62] In our diversification Risk Data, 'monoline' includes companies with a small proportion of business (less than 5% of premium) in other LOBs, e.g., Minor Line data points that we exclude from the Risk Data.

diversification is either the highest of the six values for that LOB or the lowest of the six values for that LOB. If the distribution of risk charge%s by diversification level were random, we would expect that the zero-diversification band would be the highest or lowest, on average, for about 1/3 of the LOBs. To have that be the case for 19 or more of the 32 LOBs has a probability of less than 1%. This effect is much stronger for reserves than form premium.[63]

Appendix 2/Exhibit 1A
Indicated RRFs - Variation in LOB Risk Charge% with Variation in Company Diversification

Indicated RRF by Diversification Band								
	Diversification Band							
LOB	**0**	**1**	**2**	**3**	**4**	**5**	**all**	**0 vs. rest**
A	0.35	0.28	0.25	0.19	0.18	0.19	0.22	Highest
B	0.30	0.15	0.16	0.14	0.22	0.13	0.18	Highest
C	0.57	0.34	0.37	0.48	0.40	0.28	0.35	Highest
D	0.32	0.23	0.34	0.40	0.40	0.31	0.33	
E	0.54	0.60	0.67	0.50	0.49	0.43	0.49	
F1	0.09	0.35	0.34	0.22	0.40	0.87	0.31	Lowest
F2	0.04	0.11	0.16	0.26	0.13	0.37	0.11	Lowest
G	0.39	0.08	0.38	0.50	0.31	0.63	0.45	
H	0.29	0.85	0.56	0.57	0.55	0.54	0.53	Lowest
I	0.12	0.59	0.43	0.34	0.31	0.30	0.33	Lowest
J	0.00	0.16	0.17	0.06	0.25	0.29	0.19	Lowest
K	0.34	0.39	0.74	1.28	0.64	0.50	0.56	Lowest
L	0.11	0.26	0.47	0.73	0.21	0.34	0.27	Lowest
N&P	0.17	0.41	0.40	0.44	0.51	0.48	0.42	Lowest
O	0.66	0.43	0.58	0.59	0.68	0.76	0.65	
R	0.56	1.48	0.49	1.05	0.67	0.82	0.88	
Average	0.35	0.39	0.39	0.40	0.41	0.38	0.37	Lowest

[63] Looked at for reserves and premium, separately, the situation is less clear. The probability of 12 of 16 for reserves is well under 1%, but the probability of the observed seven or more for premium is 26%, hence not unusual by itself.

Appendix 2/Exhibit 1B
Indicated PRFs - Variation in LOB Risk Charge% with Variation in Company Diversification

Indicated PRF by Diversification Band								
	Diversification Band							
LOB	**0**	**1**	**2**	**3**	**4**	**5**	**all**	**0 vs. rest**
A	1.04	0.90	0.89	0.97	0.97	0.97	0.96	Highest
B	1.01	0.95	0.95	0.98	0.97	0.97	0.97	Highest
C	0.97	0.99	0.98	1.01	1.02	0.97	0.99	
D	1.04	0.98	1.10	1.10	1.11	1.00	1.04	
E	0.87	0.95	0.84	0.88	0.87	0.88	0.88	
F1	1.37	1.49	1.37	1.45	1.39	1.19	1.46	
F2	1.07	1.19	1.22	1.26	1.36	1.24	1.15	Lowest
G	0.99	0.81	0.92	1.03	0.92	0.94	0.95	
H	1.02	1.01	0.97	1.05	1.03	1.00	1.02	
I	0.82	0.81	0.79	0.81	0.80	0.84	0.82	
J	0.82	0.78	0.84	0.85	0.83	0.82	0.83	
K	0.41	0.69	0.78	0.75	0.86	0.70	0.64	Lowest
L	0.85	0.93	0.86	0.92	0.93	0.98	0.92	Lowest
N&P	1.14	1.16	1.37	1.14	1.36	1.25	1.29	Lowest
O	0.96	1.50	1.19	1.34	1.15	1.33	1.30	Lowest
R	1.93	1.56	1.41	1.05	1.14	1.11	1.18	
Average	0.96	0.93	0.94	0.98	0.97	0.95	0.96	

To further test the statistical significance of the pattern by LOB, including the extent to which zero diversification indicated risk factors are the highest or lowest, we construct standardized differences[64] between each value and mean for the LOB across all diversification bands. Appendix 2- Exhibits 2A, 2B, and 3, below, show those standardized differences.

Appendix 2/Exhibit 2A
Indicated RRFs – Standardized Variation in LOB Risk Charge% with Variation in Company-diversification

Standard Normal Difference LOB RRF by Diversification Band vs. LOB RRF for all Div Bands						
	Diversification Band					
LOB	0	1	2	3	4	5
A	2.0	1.0	0.5	-0.6	-0.7	-0.5
B	2.0	-0.5	-0.3	-0.6	0.8	-0.8
C	2.3	-0.1	0.2	1.3	0.5	-0.8
D	-0.2	-1.8	0.2	1.1	1.2	-0.4
E	0.7	1.4	2.3	0.1	0.0	-0.7
F1	-0.9	0.2	0.2	-0.4	0.4	2.3
F2	-0.6	0.0	0.5	1.4	0.2	2.4
G	-0.4	-2.2	-0.5	0.3	-0.9	1.0
H	-1.5	2.0	0.2	0.3	0.2	0.1
I	-1.5	1.8	0.7	0.0	-0.1	-0.2
J	-1.9	-0.3	-0.3	-1.3	0.5	1.0
K	-0.7	-0.5	0.6	2.3	0.3	-0.2
L	-0.8	-0.1	1.0	2.3	-0.3	0.3
N&P	-2.3	-0.1	-0.2	0.2	0.8	0.5
O	0.1	-2.1	-0.6	-0.5	0.3	1.1
R	-0.9	1.8	-1.2	0.5	-0.6	-0.2
Average	-1.2	1.2	1.0	1.4	2.0	0.5
Avg Absolute value	1.2	1.0	0.6	0.8	0.5	0.8

[64] For each LOB, we calculate the PRF/RRF for each diversification level, minus the PRF/RRF for all diversification levels combined, divided the standard deviation across diversification levels for the LOB.

Appendix 2/Exhibit 2B
Indicated PRFs - Standardized Variation in LOB Risk Charge% with Variation in Company-diversification

Standard Normal Difference LOB PRF by Diversification Band vs. LOB RRF for all Div Bands						
	Diversification Band					
LOB	0	1	2	3	4	5
A	1.7	-1.2	-1.3	0.3	0.2	0.2
B	2.1	-0.9	-0.9	0.6	0.2	-0.1
C	-1.0	0.0	-0.6	1.1	1.5	-1.0
D	0.0	-1.1	1.2	1.1	1.4	-0.8
E	-0.2	2.2	-1.1	0.0	-0.3	0.0
F1	-1.0	0.4	-1.0	-0.1	-0.7	-2.8
F2	-0.9	0.5	0.9	1.3	2.5	1.1
G	0.6	-2.0	-0.4	1.2	-0.4	-0.1
H	0.2	-0.1	-1.9	1.3	0.6	-0.4
I	0.0	-0.4	-2.0	-0.2	-0.9	1.3
J	-0.5	-2.2	0.5	0.9	0.0	-0.4
K	-1.7	0.3	1.0	0.8	1.5	0.4
L	-1.5	0.2	-1.5	-0.1	0.2	1.3
N&P	-1.5	-1.3	0.8	-1.5	0.7	-0.4
O	-2.0	1.1	-0.7	0.2	-0.9	0.1
R	2.4	1.2	0.7	-0.4	-0.1	-0.2
Total	0.5	-1.4	-0.9	1.4	0.9	-0.4
Avg Absolute value	1.1	1.0	1.0	0.7	0.8	0.7

Appendix 2/Exhibit 3, below, shows the premium/reserve weighted averages of the absolute values of the standardized differences between each level of diversification and the all-diversification risk charges. At diversification band 0, the PRFs/RRFs, on average, are 1.1 or 1.2 standard deviations, respectively, either above or below the mean. At diversification band 5 the PRFs/RRFs are closer to the mean, 0.7 or 0.8 standard deviations, respectively. Thus, there appears to be trends towards different LOB risk charge%s in companies with different levels of diversification.

The patterns in Appendix 2/Exhibit 3 might be the result of random effects, of course. Nonetheless, the data contributing to that pattern contribute to the observations that the indicated diversification credit does not increase smoothly with higher diversification, particularly at the lower levels of diversification (bands 0-2)

Appendix 2/Exhibit 3
Variation in Indicated LOB Risk Charge% with Variation in Company-diversification

Standardized Normal Difference Average of Absolute Values		
Diversification Band	Reserves	Premium
0	1.2	1.1
1	1.0	1.0
2	0.6	1.0
3	0.8	0.7
4	0.5	0.8
5	0.8	0.7

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Appendix 3- Construction of Correlation Matrix for Diversification Testing

To apply the correlation approach, we construct a set of pairwise correlation factors, called a correlation matrix. In Solvency II correlation matrix, the factors were not calibrated from analysis of data. Rather, the factors represent an expert judgment on whether the LOB pairwise correlation is lower (0.25) or higher (0.50).

In the Solvency II 4th Quantitative Impact Analysis (QIS4) analysis, the factors were sensitivity tested with additional analysis assuming a minus or plus 25 percentage points adjustment to each "non-diagonal" value. These changes resulted in capital requirements that were 25% lower and 21% higher (respectively) than the proposed QIS4 factors. After this sensitivity analysis was completed, the selected factors were maintained at the QIS3 level, *"translating the broad support there is around these parameters and the lack of more evidence for changing the correlations"*.[65] Thus, the overall level represents an expert judgment much like the 30% MDC in the RBC Formula.

Appendix 3/Exhibit 1 shows the Solvency II correlation matrix for the 12 Solvency non-life LOBs.[66] Appendix 3/Exhibit 2 provides the LOB definitions.

Following the Solvency II approach,[67] we construct the correlation matrix using values of 25% or 50% for most of the 171 LOB-pairs. For a few LOB-pairs that we consider very highly correlated we select correlation factors of 75% or 100%.[68] Appendix 3/Exhibit 2 shows the correlation matrix that we use to test the diversification relationship.

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[65] "CEIOPS-DOC-70/10" (Page 44, paragraph B.31)
[66] (See next line)
http://www.lloyds.com/~/media/files/the%20market/operating%20at%20lloyds/solvency%20ii/2016%20guidance/2015_yesf_synd_v62.xlsx., "Non-Life and Health UW Section," Tab "Premium and Reserve Risk Params"
[67] "Advice for Band 2 Implementing Measures on Solvency II: SCR Standard Formula Article 111(d) Correlations," (former Consultation Paper 74), January 2010, pp 39-44.
[68] We select pairwise correlations of 100% for claims made and occurrence medical malpractice and for general liability, special liability and products liability. We select pairwise correlations of 75% between special property and homeowners, between private passenger automobile liability and automobile physical damage and between commercial automobile liability and automobile physical damage.

Appendix 3/Exhibit 1
Solvency II Standard Formula Correlation Matrix for Premium and Reserves

LOB/LOB	1	2	3	4	5	6	7	8	9	10	11	12
1	100%	50%	50%	25%	50%	25%	50%	25%	50%	25%	25%	25%
2	50%	100%	25%	25%	25%	25%	50%	50%	50%	25%	25%	25%
3	50%	25%	100%	25%	25%	25%	25%	50%	50%	25%	50%	25%
4	25%	25%	25%	100%	25%	25%	25%	50%	50%	25%	50%	50%
5	50%	25%	25%	25%	100%	50%	50%	25%	50%	50%	25%	25%
6	25%	25%	25%	25%	50%	100%	50%	25%	50%	50%	25%	25%
7	50%	50%	25%	25%	50%	50%	100%	25%	50%	50%	25%	25%
8	25%	50%	50%	50%	25%	25%	25%	100%	50%	25%	25%	50%
9	50%	50%	50%	50%	50%	50%	50%	50%	100%	25%	50%	25%
10	25%	25%	25%	25%	50%	50%	50%	25%	25%	100%	25%	25%
11	25%	25%	50%	50%	25%	25%	25%	25%	50%	25%	100%	25%
12	25%	25%	25%	50%	25%	25%	25%	50%	25%	25%	25%	100%

Solvency II LOBs[69]

1	Motor vehicle liability	7	Legal expenses
2	Other motor	8	Assistance
3	Marine, aviation and transport	9	Miscellaneous financial loss
4	Fire and other damage to property	10	NP casualty reinsurance
5	General liability	11	NP marine, aviation and transport reinsurance
6	Credit and suretyship	12	NP property reinsurance

Direct LOBs include proportional reinsurance of the same type.
NP = Non-proportional

69 http://www.lloyds.com/~/media/files/the%20market/operating%20at%20lloyds/solvency%20ii/2016%20guidance/2015_yesf_synd_v62.xlsx. "Non-Life and Health UW Section," Tab "Premium and Reserve Risk Params"

DCWP Report 14: RBC - Calibration of LOB Diversification in UW Risk Charges

Appendix 3/Exhibit 2

Selected DCWP Correlation Matrix – Applied by the DCWP to US NAIC LOBs for this Study

LOB	HO	PPA	CA	WC	CMP	M-Occ	M-CM	SL	OL	SP	Ohy	Fid	Other	Intl	Re Prop	Re Liab	Prod	FG	Warrnty
HO	100%	25%	25%	25%	50%	25%	25%	25%	25%	**75%**	50%	25%	25%	25%	25%	25%	25%	25%	25%
PPA	25%	100%	50%	25%	25%	25%	25%	25%	25%	25%	**75%**	25%	25%	25%	25%	25%	25%	25%	25%
CA	25%	50%	100%	50%	50%	25%	25%	50%	50%	25%	**75%**	25%	25%	25%	25%	25%	50%	25%	25%
WC	25%	25%	50%	100%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
CMP	50%	25%	50%	25%	100%	25%	25%	50%	50%	50%	25%	25%	25%	25%	25%	25%	50%	25%	25%
M-Occ	25%	25%	25%	25%	25%	100%	**100%**	50%	50%	25%	25%	25%	25%	25%	25%	25%	50%	25%	25%
M-CM	25%	25%	25%	25%	25%	**100%**	100%	50%	50%	25%	25%	25%	25%	25%	25%	25%	50%	25%	25%
SL	25%	25%	50%	25%	50%	50%	50%	100%	**75%**	25%	25%	25%	25%	25%	25%	50%	**100%**	25%	25%
OL	25%	25%	50%	25%	50%	50%	50%	**75%**	100%	25%	50%	50%	25%	50%	25%	50%	**100%**	25%	25%
SP	**75%**	25%	25%	25%	50%	25%	25%	25%	25%	100%	25%	25%	25%	25%	50%	25%	25%	25%	25%
Phy	50%	**75%**	**75%**	25%	25%	25%	25%	25%	50%	25%	100%	25%	25%	25%	25%	25%	25%	25%	25%
Fid	25%	25%	25%	25%	25%	25%	25%	25%	50%	25%	25%	100%	25%	25%	25%	50%	25%	25%	25%
Other	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	100%	25%	25%	25%	25%	25%	25%
Intl	25%	25%	25%	25%	25%	25%	25%	25%	50%	25%	25%	25%	25%	100%	25%	25%	25%	25%	25%
Re Prop	25%	25%	25%	25%	25%	25%	25%	25%	25%	50%	25%	25%	25%	25%	100%	25%	25%	25%	25%
Re Liab	25%	25%	25%	25%	25%	25%	25%	50%	50%	25%	25%	50%	25%	25%	25%	100%	50%	25%	25%
Prod	25%	25%	50%	25%	50%	50%	50%	**100%**	**100%**	25%	25%	25%	25%	25%	25%	50%	100%	25%	25%
FG	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	100%	25%
Warrnty	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	100%

Note: Off diagonal values other than 25%, 50% are in bold.

LOB Definitions

LOB	Abbreviation	LOB	Abbreviation	LOB	Abbreviation
Homeowners/Farmowners	HO	Special Liab	SL	International	Intl
Priv. Passenger Auto	PPA	Other Liab-Occ and CM	OL	Reinsurance-Fin and Prop	Re Prop
Commercial Auto	CA	Spec Property	SP	Reinsurance-Liab	Re Liab
Workers Compensation	WC	Auto Physical Damage	Phy	Products Liability-Occ and CM	Prod
Commercial Multi-peril	CMP	Fidelity & Surety	Fid	Financial/Mort Guarantee	FG
Medical Prof Liab - Occ	P-Occ	Other	Other	Warranty	Warrnty
Medical Prof Liab - CM	M-CM				

Appendix 4 - Diversification Based on Correlation Matrix Approach

In Appendix 4/Exhibits 1 and 2, we compare how well diversification formulas for CoMaxLine% and correlation matrix approach fit the experience by company size and diversification level, for reserves and premium respectively.

Part 1 of these exhibits shows the expected risk charge%s, before diversification. These are the unweighted averages of the expected risk charge%s, for each company-year in the size/diversification bands, before application of diversification. For the CoMaxLine% section the values are the same as the values in Table 3-16. For the correlation matrix approach, the values are very similar to the values in Table 3-16. This should be the case, as the values are calculated before any diversification effect. Therefore, the values differ only to the extent that the diversification band under CoMaxLine% Approach is different from the diversification band under the correlation matrix approach.

Part 2 of these exhibits shows the indicated risk charge%s. These values are the 87.5th percentile RRR and the 87.5th percentile AYUL% for all company-years in the size/diversification cell. For the CoMaxLine% column, the values are the same as the values in Table 3-15. For the correlation matrix approach, the values are very similar to the values in Table 3-15. This is the case because the values differ only to the extent that the diversification band under CoMaxLine% Approach is different from the diversification band under the correlation matrix approach.

Part 3 of these exhibits shows the current average diversification credit.

Using Parts 1, 2 and 3, we calculate the factor that, when applied to the current average diversification credit, minimizes the difference between actual experience (Part 2) and expected experience [Part 1*(1-Part 3)] for company size/diversification bands C3.E5. We determine that factor through an iterative process. We manually "goal seek' to produce the adjustment to the Part 3 diversification credit that minimizes the sum of the differences between (a) Part 2 values and (b) the values of [Part 1*(1-Part 3) * test adjustment to the average diversification credit], for the cells in section C3.E5. In the first line below Part 2, we show the increase/decrease in diversification credit that is necessary to achieve the target diversification credit, e.g., +120% for CoMaxLine%, or an MDC of 66%, (1+1.2) x 30%.[70,71]

Part 4 equals Part 1 times the adjusted average diversification credit.

Part 5 shows the differences between indicated risk charge%s (Part 2) and expected risk charge%s at the target diversification level (Part 4).

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[70] For the correlation matrix approach, the percentage is the effect that would need to be achieved by changes in pairwise correlation values.

[71] Immediately below that value, we show the remaining difference between Part 2 values and Part 5. Part 5 values are the differences between indicated and formula risk charge%s after applying adjustment factor.

Appendix 4/Exhibit 1 – Reserves
Diversification Analysis by LOB-size/Diversification (5x6 analysis)
Calculation of Normalized Variability with Array by Method

CoMaxLine%/Single Factor Risk Charge

Diversif. Band Quintiles	Expected Risk - No diversification Credit-Part 1 Size Band (Quinitiles) A	B	C	D	E
0	34%	34%	33%	31%	31%
1	28%	28%	31%	33%	29%
2	31%	31%	31%	32%	31%
3	32%	32%	34%	33%	38%
4	34%	33%	37%	37%	40%
5	36%	36%	37%	36%	38%
All Ex 0	31%	32%	34%	34%	36%

Diversif. Band Quintiles	Indicated Risk - Part 2 Size Band (Quinitiles) A	B	C	D	E
0	63%	38%	25%	21%	18%
1	53%	34%	27%	30%	15%
2	54%	35%	30%	29%	17%
3	75%	39%	27%	22%	25%
4	45%	36%	32%	22%	29%
5	37%	30%	24%	24%	26%
All Ex 0	55%	35%	28%	25%	24%

Calibration to Target Diversification Level 120.0%

0.004

Diversif. Band Quintiles	Current Average Diversification- Part 3 Size Band (Quinitiles) A	B	C	D	E
0	0%	0%	0%	0%	0%
1	2%	2%	2%	2%	2%
2	5%	5%	5%	5%	5%
3	9%	9%	9%	10%	9%
4	13%	13%	13%	13%	13%
5	17%	17%	18%	18%	19%
All Ex 0	8%	8%	9%	10%	11%

Diversif. Band Quintiles	Expected Risk With Target Div Level- Part 4 Size Band (Quinitiles) A	B	C	D	E
0	34%	34%	33%	31%	31%
1	27%	27%	30%	32%	28%
2	27%	27%	28%	28%	27%
3	25%	26%	27%	26%	30%
4	24%	23%	26%	26%	28%
5	22%	22%	22%	22%	23%
All Ex 0	26%	26%	27%	27%	27%

Diversif. Band Quintiles	Actual vs. Expected - Part 5 Size Band (Quinitiles) A	B	C	D	E
0	29%	4%	-8%	-10%	-13%
1	27%	6%	-3%	-2%	-13%
2	27%	8%	2%	0%	-10%
3	50%	14%	0%	-4%	-5%
4	21%	13%	6%	-3%	0%
5	14%	8%	2%	2%	3%
All Ex 0	29%	9%	1%	-2%	-3%

Correlation/Single Factor Risk Charge

Diversif. Band Quintiles	Expected Risk - No diversification Credit-Part 1 Size Band (Quinitiles) A	B	C	D	E
0	34%	34%	33%	30%	29%
1	29%	31%	34%	39%	39%
2	32%	33%	35%	36%	36%
3	32%	33%	35%	35%	38%
4	32%	31%	34%	35%	38%
5	34%	30%	32%	32%	36%
All Ex 0	31%	32%	34%	35%	37%

Diversif. Band Quintiles	Indicated Risk - Part 2 Size Band (Quinitiles) A	B	C	D	E
0	63%	39%	26%	22%	16%
1	50%	34%	28%	31%	24%
2	65%	39%	36%	32%	22%
3	62%	30%	26%	29%	30%
4	35%	34%	25%	22%	26%
5	38%	30%	24%	16%	23%
All Ex 0	54%	35%	28%	25%	25%

Calibration to Target Diversification Level 50.0%

0.004

Diversif. Band Quintiles	Current Average Diversification- Part 3 Size Band (Quinitiles) A	B	C	D	E
0	0%	0%	0%	0%	0%
1	3%	2%	2%	2%	2%
2	8%	8%	8%	8%	8%
3	14%	14%	14%	14%	14%
4	20%	20%	20%	19%	20%
5	25%	25%	25%	26%	26%
All Ex 0	10%	11%	13%	15%	17%

Diversif. Band Quintiles	Expected Risk With Target Div Level- Part 4 Size Band (Quinitiles) A	B	C	D	E
0	34%	34%	33%	30%	29%
1	28%	30%	33%	38%	38%
2	28%	29%	31%	31%	31%
3	26%	26%	27%	27%	30%
4	23%	22%	24%	25%	27%
5	21%	19%	20%	19%	22%
All Ex 0	26%	26%	27%	27%	28%

Diversif. Band Quintiles	Actual vs. Expected - Part 5 Size Band (Quinitiles) A	B	C	D	E
0	29%	6%	-7%	-9%	-13%
1	23%	4%	-4%	-7%	-13%
2	37%	10%	6%	0%	-9%
3	36%	4%	-1%	2%	0%
4	12%	12%	1%	-3%	-1%
5	16%	11%	4%	-4%	1%
All Ex 0	27%	8%	0%	-2%	-3%

Appendix 4/Exhibit 2 – Premium
Diversification Analysis by LOB-size/Diversification (5x6 analysis)
Calculation of Normalized Variability with Array by Method

CoMaxLine%/Single Factor Risk Charge

Diversif. Band Quintiles	Expected Risk - No diversification Credit-Part 1				
	Size Band (Quinitiles)				
	A	B	C	D	E
0	28%	29%	29%	31%	30%
1	26%	28%	28%	32%	31%
2	26%	25%	24%	24%	26%
3	23%	24%	23%	24%	25%
4	23%	24%	23%	24%	24%
5	24%	24%	23%	23%	24%
All Ex 0	25%	25%	24%	25%	25%

Diversif. Band Quintiles	Indicated Risk Charge - Part 2				
	Size Band (Quinitiles)				
	A	B	C	D	E
0	56%	29%	26%	27%	37%
1	45%	21%	25%	22%	39%
2	42%	19%	15%	16%	15%
3	44%	21%	17%	18%	17%
4	33%	14%	18%	18%	16%
5	56%	22%	15%	16%	15%
All Ex 0	44%	19%	18%	18%	17%

Calibration to Target Diversification Level 75.0%

(0.004)

Diversif. Band Quintiles	Current Average Diversification-Part 3				
	Size Band (Quinitiles)				
	A	B	C	D	E
0	0%	0%	0%	0%	0%
1	4%	4%	4%	4%	4%
2	9%	9%	9%	10%	10%
3	13%	13%	**13%**	**13%**	**13%**
4	16%	16%	**16%**	**17%**	**17%**
5	20%	20%	**20%**	**21%**	**21%**
All Ex 0	10%	11%	12%	13%	16%

Diversif. Band Quintiles	Modeled Risk With Target Div Level - Part 4				
	Size Band (Quinitiles)				
	A	B	C	D	E
0	28%	29%	29%	31%	30%
1	24%	25%	25%	29%	29%
2	22%	21%	20%	20%	22%
3	18%	19%	18%	18%	19%
4	16%	17%	17%	17%	17%
5	16%	15%	15%	15%	15%
All Ex 0	21%	20%	19%	19%	18%

Diversif. Band Quintiles	Actual vs. Expected - Part 5				
	Size Band (Quinitiles)				
	A	B	C	D	E
0	28%	0%	-3%	-4%	7%
1	20%	-5%	0%	-7%	9%
2	21%	-2%	-5%	-4%	-7%
3	26%	2%	-1%	0%	-3%
4	17%	-3%	2%	1%	-1%
5	40%	7%	1%	2%	0%
All Ex 0	23%	-1%	-1%	-2%	-2%

Correlation/Single Factor Risk Charge

Diversif. Band Quintiles	Expected Risk - No diversification Credit-Part 1				
	Size Band (Quinitiles)				
	A	B	C	D	E
0	28%	30%	30%	34%	35%
1	23%	23%	22%	23%	21%
2	24%	24%	24%	25%	25%
3	25%	25%	23%	24%	24%
4	25%	25%	23%	23%	24%
5	23%	24%	24%	24%	25%
All Ex 0	24%	24%	23%	24%	24%

Diversif. Band Quintiles	Indicated Risk Charge - Part 2				
	Size Band (Quinitiles)				
	A	B	C	D	E
0	57%	30%	28%	29%	46%
1	62%	17%	18%	17%	13%
2	35%	18%	18%	15%	18%
3	33%	18%	18%	18%	14%
4	51%	18%	15%	17%	16%
5	48%	25%	18%	17%	15%
All Ex 0	43%	19%	17%	17%	15%

Calibration to Target Diversification Level 45.0%

0.004

Diversif. Band Quintiles	Current Average Diversification-Part 3				
	Size Band (Quinitiles)				
	A	B	C	D	E
0	0%	0%	0%	0%	0%
1	3%	3%	3%	3%	3%
2	9%	9%	9%	9%	9%
3	15%	15%	**16%**	**16%**	**16%**
4	21%	21%	**21%**	**22%**	**22%**
5	28%	27%	**28%**	**28%**	**29%**
All Ex 0	10%	13%	14%	17%	21%

Diversif. Band Quintiles	Modeled Risk With Target Div Level - Part 4				
	Size Band (Quinitiles)				
	A	B	C	D	E
0	28%	30%	30%	34%	35%
1	22%	22%	21%	22%	20%
2	21%	21%	21%	21%	21%
3	20%	19%	18%	19%	18%
4	18%	17%	16%	16%	16%
5	14%	14%	14%	14%	15%
All Ex 0	20%	20%	19%	18%	17%

Diversif. Band Quintiles	Actual vs. Expected - Part 5				
	Size Band (Quinitiles)				
	A	B	C	D	E
0	29%	0%	-3%	-5%	11%
1	40%	-5%	-4%	-5%	-6%
2	14%	-2%	-3%	-6%	-3%
3	13%	-2%	-1%	0%	-4%
4	33%	1%	-1%	1%	-1%
5	34%	11%	4%	2%	0%
All Ex 0	23%	-1%	-1%	-1%	-2%

Appendix 5- Diversification Analysis – Results using Risk Factors by LOB-Size

In this section, we address the extent to which our findings regarding diversification with CoMaxLine% Approach would be affected if the RBC Formula used risk factors that vary by LOB-size.

This question is motivated, in part, because we observe that LOB-size, company-size and diversification level are inter-related. For example, we observe that larger LOB-sizes indicate risk charge%s that are lower than the risk charges%s indicated by smaller LOB-sizes. Therefore, it could be the case higher indicated diversification credits are a proxy for lower LOB risk charge%s for larger companies.

To analyze that question, we first use the risk data to construct reserve and premium risk factors that vary by LOB-size.[72] Appendix 5/Exhibit 1, below, shows those risk factors.

[72] We develop these risk factors by LOB-size using our calibration approach, described in DCWP Reports 6 and 7, applied separately to each LOB-size band. For this purpose, we measure "LOB-size" for each company/LOB/year as the percentile of reserve/premium amount relative to reserve/premium for all Company/LOBs in that year.

Appendix 5/Exhibit 1
Indicated PRC% and RRC% by LOB-size

Premium Risk Charge = PRF + CER - 100% by LOB-Size										
Line of Business	0%-15%	15%-25%	25%-35%	35%-45%	45%-55%	55%-65%	65%-75%	75%-85%	85%-95%	95%-100%
A- Homeowners/Farmowner	58.8%	32.4%	28.6%	26.5%	24.1%	21.5%	25.9%	24.0%	22.9%	24.8%
B- Private Passenger Auto	49.6%	27.1%	25.5%	26.5%	22.3%	22.3%	21.4%	21.2%	17.1%	14.7%
C- Commercial Auto	56.9%	37.9%	31.7%	30.3%	29.7%	28.1%	29.7%	28.1%	25.2%	24.6%
D - Workers Compensation	58.3%	49.0%	37.2%	34.8%	28.8%	24.5%	22.2%	22.4%	28.5%	37.9%
E - Commercial Multi-Peril	44.8%	23.1%	23.1%	23.7%	25.4%	24.2%	22.2%	21.0%	23.5%	25.5%
F1 - Med Prof Liab-Occ	171.5%	84.1%	54.5%	72.1%	54.1%	71.1%	97.6%	71.0%	66.0%	71.7%
F2 - Med Prof Liab-CM	104.0%	28.5%	43.5%	34.2%	31.7%	45.6%	52.1%	37.9%	49.5%	45.6%
G - Special Liability	57.6%	45.8%	28.9%	34.5%	38.5%	21.4%	30.9%	28.7%	19.2%	4.4%
H - Other Liability	68.6%	32.7%	38.2%	37.6%	32.8%	31.7%	28.8%	32.6%	26.5%	28.4%
I - Special Property	32.6%	9.5%	9.6%	12.5%	9.9%	15.4%	14.6%	18.4%	16.1%	18.2%
J - Auto Physical Damage	29.1%	13.1%	9.7%	9.4%	8.7%	7.2%	10.0%	6.6%	4.4%	4.2%
K - Fidelity/Surety	43.1%	13.7%	8.8%	21.1%	11.9%	1.3%	7.6%	1.0%	10.2%	1.0%
L - Other	44.9%	27.0%	23.6%	19.1%	27.6%	31.0%	29.6%	15.3%	33.3%	27.1%
M - International	46.8%	25.1%	25.1%	25.7%	27.4%	26.2%	24.2%	23.0%	25.5%	27.5%
N&P - Reinsurance-Prop/Fin	109.6%	53.0%	85.1%	55.3%	40.0%	65.9%	43.8%	47.0%	32.7%	26.4%
O - Reinsurance-Liabiity	95.7%	68.4%	42.2%	53.5%	51.9%	58.3%	54.1%	42.1%	61.8%	28.6%
R - Products Liability	72.7%	14.1%	80.8%	23.9%	81.8%	46.9%	131.9%	45.5%	39.8%	34.4%
S - Financial/Mort Guarante	43.1%	13.7%	8.8%	21.1%	11.9%	1.3%	7.6%	1.0%	10.2%	1.0%
T - Warranty	44.8%	23.1%	23.1%	23.7%	25.4%	24.2%	22.2%	21.0%	23.5%	25.5%

Reserve Risk Charge = RRF by LOB-Size										
Line of Business	0%-15%	15%-25%	25%-35%	35%-45%	45%-55%	55%-65%	65%-75%	75%-85%	85%-95%	95%-100%
A- Homeowners/Farmowner	83.3%	41.1%	33.6%	28.8%	27.7%	27.5%	14.1%	8.3%	12.2%	10.4%
B- Private Passenger Auto	79.4%	41.0%	31.3%	26.0%	19.3%	13.5%	15.7%	8.7%	5.2%	8.0%
C- Commercial Auto	126.5%	69.8%	44.9%	39.4%	35.3%	32.4%	26.0%	34.0%	23.1%	13.1%
D - Workers Compensation	69.5%	36.4%	49.1%	41.7%	44.6%	29.1%	30.7%	24.0%	22.8%	27.3%
E - Commercial Multi-Peril	134.9%	76.4%	57.1%	52.4%	58.1%	54.2%	41.1%	32.9%	41.2%	31.5%
F1 - Med Prof Liab-Occ	195.2%	67.8%	32.8%	31.4%	17.4%	58.4%	40.2%	12.2%	7.6%	7.1%
F2 - Med Prof Liab-CM	67.2%	20.1%	21.0%	14.8%	12.6%	12.0%	10.6%	1.0%	1.0%	1.0%
G - Special Liability	172.6%	18.4%	78.9%	119.6%	39.4%	36.0%	35.3%	31.8%	29.5%	6.0%
H - Other Liability	155.8%	81.0%	61.5%	44.8%	37.6%	35.4%	36.6%	55.2%	71.3%	67.2%
I - Special Property	120.0%	45.3%	35.2%	29.1%	27.0%	25.9%	26.1%	34.1%	36.4%	43.4%
J - Auto Physical Damage	62.8%	44.6%	19.4%	15.8%	27.1%	15.0%	9.4%	10.3%	24.9%	9.2%
K - Fidelity/Surety	188.9%	43.7%	103.7%	71.4%	127.3%	112.4%	33.5%	42.4%	26.2%	30.8%
L - Other	118.6%	38.7%	37.9%	12.9%	19.1%	11.9%	22.7%	91.3%	19.1%	27.9%
M - International	136.9%	78.4%	59.1%	54.4%	60.1%	56.2%	43.1%	34.9%	43.2%	33.5%
N&P - Reinsurance-Prop/Fin	74.1%	39.7%	51.3%	34.5%	72.4%	53.1%	40.0%	42.4%	31.3%	6.5%
O - Reinsurance-Liabiity	114.1%	55.2%	78.7%	58.3%	94.0%	43.8%	46.4%	68.8%	66.4%	104.2%
R - Products Liability	138.9%	68.7%	73.0%	137.1%	70.0%	28.2%	180.3%	74.6%	22.8%	1.0%
S - Financial/Mort Guarante	188.9%	43.7%	103.7%	71.4%	127.3%	112.4%	33.5%	42.4%	26.2%	30.8%
T - Warranty	134.9%	76.4%	57.1%	52.4%	58.1%	54.2%	41.1%	32.9%	41.2%	31.5%

Minimum of 1% PRC% and PRF% applied as needed

<u>2x2 Analysis – Risk Factors by LOB-size</u>

Table 3-5 shows the indicated MDC based on all multiline companies and all company sizes larger than the smallest 20%. We found that the indicated MDC was 62% and 65% for reserve risk and premium risk respectively. Appendix 5/Exhibit 2, below, shows that if the RBC Formula used LOB risk factors based on LOB-size, the indicated MDC would be higher, 76% and 85% for reserves and premium, respectively (column C/line 5).

Appendix 5/Exhibit 2
Indicated MDC – 2x2 Analysis

	Reserves	Single RRF	RRF by LOB-size
	(A)	(B)	(C)
#	Item	Premium	Premium
1	Observed Risk - 87.5th RRR/AYUL	27.2%	27.2%
2	Expected Risk - 87.5th RRR/AYUL before diversification	34.2%	36.2%
3	Indicated Diversification Credit - 100%-(1)/(2)%	20.6%	24.9%
4	Current Average Diversification Credit	9.9%	9.9%
5	Indicated Maximum Credit (3)/(4) * 30%	62.5%	75.7%

	Premium	Single PRF	PRF by LOB-size
	(A)	(B)	(C)
#	Item	Reserves	Reserves
1	Observed Risk - 87.5th RRR/AYUL	17.8%	17.8%
2	Expected Risk - 87.5th RRR/AYUL before diversification AYULedit	25.0%	28.7%
3	Indicated Diversification Credit - 100%-(1)/(2)%	28.8%	37.8%
4	Current Average Diversification Credit	13.3%	13.3%
5	Indicated Maximum Credit (3)/(4) * 30%	64.9%	85.4%

The column "Single PRF/RRF" is the same as Table3-5

Notes:
The values in column B are the same as the values in Table 3-5.
Row 1– Observed Risk – This is based on LRs and RRRs and is not affected by the expected risk calculation. Hence columns B and C have the same values.
Row 2 – Expected risk calculated using the single risk factor or risk factor by LOB-size, hence columns B and C are not the same.
Row 3 – Calculated as shown.
Row 4 – Current average diversification credit. It is not affected by the risk factors; hence column B and C are the same values.
Row 5 – Calculated as shown.

5x6 Analysis – Risk Factors by LOB-size

Table 3-19, in which risk factors by LOB do not vary by LOB-size, shows that the indicated MDC is generally greater than 50% for both reserve risk and premium risk, for company size/diversification bands C3 through E5. We repeat Table 3-19 below, labeled Appendix 5/Exhibit 3.

Appendix 5/Exhibit 4, below shows the corresponding indicated MDC values when the LOB-risk factors vary by LOB-size. Table 3-19 shows unexpected negative indicated MDC values for the company size bands A and B, the smallest sizes. These negative values do not appear in Appendix 5/Exhibit 4, where the LOB risk factors vary by LOB-size. The observation that the negative indicated risk factors are eliminated is evidence that the negative values in Table 3-19 are due to the variation in LOB-risk factors by IOB-size.

Looking at the indicated MDC in each of yellow/bold cells, in Appendix 5/Exhibit 4, we see that values often exceed 50%, and average over 50%.

Appendix 5/Exhibit 3
Indicated MDC - Single risk factor by LOB for all LOB-sizes
Copy of Table 3-19

Diversif. Band Quintiles	Reserves					Premium				
	Size Band (Quintiles)					Size Band (Quintiles)				
	A	B	C	D	E	A	B	C	D	E
0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	-1524.0%	-310.2%	247.1%	165.0%	731.8%	-513.5%	167.1%	61.4%	218.5%	-159.0%
2	-417.5%	-69.6%	27.3%	59.1%	248.8%	-203.2%	73.4%	115.6%	98.9%	131.1%
3	-431.7%	-71.6%	**61.9%**	**105.7%**	**108.8%**	-208.9%	35.0%	**58.9%**	**54.9%**	**78.1%**
4	-70.3%	-20.9%	**28.7%**	**87.0%**	**64.0%**	-84.6%	78.8%	**39.9%**	**43.7%**	**63.3%**
5	-2.7%	24.8%	**57.2%**	**58.0%**	**54.3%**	-200.3%	9.6%	**48.5%**	**42.8%**	**52.9%**
All Ex 0	-291.9%	-41.5%	57.7%	80.3%	91.0%	-236.8%	62.9%	64.3%	66.3%	63.9%

Appendix 5/Exhibit 4
Indicated MDC - LOB-risk factors by LOB-size

Diversif. Band Quintiles	Reserves					Premium				
	Size Band (Quintiles)					Size Band (Quintiles)				
	A	B	C	D	E	A	B	C	D	E
0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	449.6%	383.1%	296.2%	4.2%	475.6%	139.4%	295.0%	93.8%	234.6%	-203.4%
2	172.3%	147.9%	55.1%	5.4%	165.1%	77.1%	159.3%	138.5%	102.2%	121.1%
3	39.6%	69.5%	**87.5%**	**80.0%**	**81.2%**	31.0%	112.0%	**82.2%**	**59.3%**	**69.1%**
4	111.2%	66.3%	**50.0%**	**79.3%**	**46.5%**	60.8%	123.9%	**69.1%**	**47.4%**	**55.1%**
5	109.3%	87.9%	**75.6%**	**52.1%**	**37.6%**	-15.0%	75.3%	**75.9%**	**48.7%**	**47.8%**
All Ex 0	129.2%	104.2%	83.0%	62.0%	60.3%	53.2%	137.6%	91.8%	71.5%	56.4%

Appendix 5/Exhibit 5 below compares the error statistics for CoMaxLine% Approach and correlation matrix approach with risk factors that vary (by LOB-size) and risk factors that are the same for all LOB-sizes (as in RBC Formula).

Appendix 5/Exhibit 5
Error Statistics - Diversification Models/Size Bands
Error Measured as % of Reserves/Premium
[Green Highlight indicates the lower value within each pair of models]

Standard Deviations – Part A

Points Included	Reserves			
	NAIC	Correlation	NAIC	Correlation
	Single LOB Risk Factor		LOB Risk Factor Varies	
All Points (25 points)	0.13	0.11	0.08	0.12
Exclude Smallest (20 points)	0.07	0.06	0.04	0.05
Include only Largest (9 points)	0.03	0.02	0.029	0.032

Points Included	Premium			
	NAIC	Correlation	NAIC	Correlation
	Single LOB Risk Factor		LOB Risk Factor Varies	
All Points (25 points)	0.11	0.12	0.09	0.08
Exclude Smallest (20 points)	0.040	0.038	0.07	0.05
Include only Largest (9 points)	0.01	0.02	0.021	0.022

Average Error - Part B

Points Included	Reserves			
	NAIC	Correlation	NAIC	Correlation
	Single LOB Risk Factor		LOB Risk Factor Varies	
All Points (25 points)	6.5%	4.7%	-4.3%	-3.5%
Exclude Smallest (20 points)	1.2%	0.7%	-1.8%	-2.3%
Include only Largest (9 points)	0%	0%	0%	0%

Points Included	Premium			
	NAIC	Correlation	NAIC	Correlation
	Single LOB Risk Factor		LOB Risk Factor Varies	
All Points (25 points)	4.4%	4.3%	-0.2%	-2.2%
Exclude Smallest (20 points)	-0.7%	-1.2%	-1.7%	-4.0%
Include only Largest (9 points)	0%	0%	0%	0%

Average Absolute Error - Part C

Points Included	Reserves			
	NAIC	Correlation	NAIC	Correlation
	Single LOB Risk Factor		LOB Risk Factor Varies	
All Points (25 points)	9.7%	8.0%	6.2%	8.0%
Exclude Smallest (20 points)	5.3%	4.9%	3.5%	4.2%
Include only Largest (9 points)	2.9%	1.9%	2.7%	2.9%

Points Included	Premium			
	NAIC	Correlation	NAIC	Correlation
	Single LOB Risk Factor		LOB Risk Factor Varies	
All Points (25 points)	7.4%	7.7%	5.8%	6.0%
Exclude Smallest (20 points)	3.0%	3.1%	5.1%	4.9%
Include only Largest (9 points)	1.1%	1.5%	1.8%	2.0%

The type of information in Appendix 5/Exhibit 5 is the same as Table 4-1. The values in the columns labeled "single risk factor" are the same as the values in Table 4-1.

For risk factors that vary by LOB-size, the CoMaxLine% Approach (labeled NAIC) has lower error statistics in more tests than the correlation matrix approach (7 of 8 tests for reserves and 5 of 8 tests for premium). Hence, evening using risk charges by LOB-size, it does not appear that the correlation matrix fits the data better than CoMaxLine% Approach.