

# **Risk-Based Capital Line of Business Diversification: Current RBC Approach vs. Correlation Matrix Approach**

Report 13 of the CAS Risk-Based Capital (RBC) Research Working Parties  
Issued by the RBC Dependencies and Calibration Working Party (DCWP)

Abstract: The NAIC RBC Formula treatment of line of business (LOB) diversification (referred to in this paper as the CoMaxLine% Approach) is very different from the Solvency II Standard Formula treatment. In this paper we show that, notwithstanding the differences, the NAIC RBC Formula, the correlation matrix approach used in Solvency II<sup>1</sup> and the Herfindahl-Hirschman Index (HHI), widely used in economics, all produce similar risk-based capital underwriting risk values, for most companies.

To the extent that there are differences between the CoMaxLine% and correlation matrix approaches, the differences are due, in part, to the fact that CoMaxLine% calculates diversification based on premium or reserve volume while the correlation matrix approach calculates diversification based on premium risk or reserve risk. To examine this feature of the RBC Formula, we also apply the CoMaxLine% idea to risk by LOB rather than volume by LOB. We refer to that as CoMaxLine%-Risk. The differences between CoMaxLine%-Risk and the correlation matrix approach are smaller than the differences to the RBC CoMaxLine% Approach.

This is one of several papers being issued by the Risk-Based Capital (RBC) Dependencies and Calibration Working Party.

Keywords: Risk-Based Capital, Capital Requirements, Analyzing/Quantifying Risks, Assessing/Prioritizing Risks, Integrating Risks, dependency, correlation.

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## **1. INTRODUCTION**

The Property & Casualty NAIC RBC Formula (“RBC Formula”) has six main risk categories,  $R_0 - R_5$ . Underwriting (UW) risk is represented in two of these categories,  $R_4^2$  and  $R_5$ , reserve risk and premium risk, respectively. In this work, we focus on the UW risk elements,  $R_4$  and  $R_5$ . Following the RBC Formula, we calculate the UW portion of the

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<sup>1</sup> Using a limited number of correlation matrix values, e.g., only 25% and 50% in the Solvency II Standard Formula and 25%, 50%, 75% and 100% in our RBC equivalent matrix.

<sup>2</sup> When applied, 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  $R_4$ .

Company Action Level RBC Value<sup>3,4</sup> as the square root of  $R_4$  squared plus  $R_5$  squared<sup>5</sup> and refer to the resulting quantity as the RBC UW Risk Value.<sup>6</sup>

$R_4$  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).<sup>7</sup>

For each company, the LCF calculation uses the ratio of (a) the largest of the 19 LOB<sup>8</sup> reserves, to (b) the total all-lines reserves.<sup>9</sup> Similarly, for each company, the PCF calculation uses the ratio of (a) the largest of the 19 LOB written premiums, to (b) the total all-lines written premium.<sup>10</sup> The LCF and PCF are values between 0.0 and 1.0 that represent the degree of concentration across LOBs, within  $R_4$  and  $R_5$ , respectively. A company with greater diversification across its LOBs will have smaller LCF and PCF values than a less diversified company.

We refer to this method of measuring concentration as the Company Maximum Line Percentage of Business or the “CoMaxLine% Approach.” We refer to the ratios computed as the CoMaxLine%<sub>PREMIUM</sub> and the CoMaxLine%<sub>RESERVES</sub>, or CoMaxLine% generically for either.

The CoMaxLine% Approach in the NAIC RBC Formula is very different in concept from the Solvency II Standard Formula correlation matrix approach. In this paper we show that,

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<sup>3</sup> That is the Company Action Level RBC as if the  $R_0$ - $R_3$  and  $R_3$ -Reinsurance Credit Risk RBC values were zero.

<sup>4</sup> In all cases in the paper, when we refer to “RBC UW Risk Value” we refer to the Company Action Level RBC. The RBC value in the Annual Statement is the Authorized Control Level, equal to 50% of the Company Action Level.

<sup>5</sup> Note that we compare diversification formulas using the UW portion of RBC rather than the total RBC value. Had we compared using the total RBC value, the percentage differences between companies would have appeared smaller than the differences displayed in Tables 3-1, 3-2, and 3-3 below.

<sup>6</sup> The RBC Formula treats premium risk and reserve risk as independent risks. We are not testing alternatives to the way that the RBC Formula combines premium risk and reserve risk.

<sup>7</sup> 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 contract adjustment.

<sup>8</sup> There are 22 LOBs in the Annual Statement Schedule P. In the RBC forms, those are consolidated into 19 LOBs. Other Liability Occurrence and Other Liability Claims-Made LOBs are combined and treated as one LOB. Products Occurrence and Products Claims-Made are combined and treated as one LOB. Reinsurance: nonproportional assumed property and reinsurance: nonproportional assumed financial LOBs are combined and treated as one LOB. NAIC, 2010, “Property and Casualty Risk-Based Capital Forecasting & Instructions.” page 19.

<sup>9</sup> The reserves used to compute the ratio are the reserves for unpaid claims and claim expenses, net of reinsurance, as of the most recent year-end including both adjusting and other expenses and defense and cost containment expenses.

<sup>10</sup> The premiums used in this calculation are the most recent year’s written premiums net of reinsurance.

notwithstanding the conceptual differences, the NAIC RBC Formula, the correlation matrix approach used in Solvency II and the Herfindahl-Hirschman Index (HHI), widely used in economics to measure concentration, produce similar RBC UW Risk Values, for most companies.

This paper is focused solely on a comparison of the RBC UW Risk Values produced by several methods of reflecting diversification among lines of business. In this paper we do not evaluate the CoMaxLine% parameters or the parameters for other methods of measuring concentration.<sup>11</sup>

In Section 2. we describe the alternative diversification approaches. In Section 3, we compare the UW Risk RBC Values, by company, that result from the different approaches.

### **1.1 Terminology, Assumed Reader Background and Disclaimer**

This paper assumes the reader is generally familiar with the property/casualty RBC Formula.<sup>12</sup>

In this paper we use the term “diversification” rather than its complement<sup>13</sup> “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.

The “working party” and “DCWP” refer to the CAS RBC Dependencies and Calibration Working Party.

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

Nether the authors nor DCWP make recommendations to the NAIC or any other body. This material is for the information of CAS members, policy makers, actuaries and others who might make recommendations regarding the future of the P&C RBC Formula. In particular,

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<sup>11</sup> In DCWP Report 14 we evaluate the CoMaxLine% parameters.

<sup>12</sup> 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.

<sup>13</sup> A company with a concentration ratio of 80% can equivalently be described as a having a diversification ratio of 20%, 100%-80%.

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. Alternative Diversification Formulas

### RBC Diversification Approach

The RBC Formula uses the CoMaxLine% Approach and a maximum diversification credit (MDC) of 30% to calculate PCFs and LCFs as follows:

$$PCF_{COMPANY} = 0.7 + 0.3 * CoMaxLine\%_{PREMIUM, COMPANY}$$

$$LCF_{COMPANY} = 0.7 + 0.3 * CoMaxLine\%_{RESERVES, COMPANY}$$

These can also be written as:

$$PCF_{COMPANY} = 1.0 - 0.3 * (1.0 - CoMaxLine\%_{PREMIUM, COMPANY})$$

$$LCF_{COMPANY} = 1.0 - 0.3 * (1.0 - CoMaxLine\%_{RESERVES, COMPANY})$$

Thus, the company diversification credit is  $0.3 * (1 - CoMaxLine\%)$ .

For mono-line companies, CoMaxLine% and the PCF/LCF are 1.00. The maximum credit of 30% would be achievable only if there were an infinite number of LOBs. Since there are 19 statutory lines of business used in the RBC Formula the smallest value of CoMaxLine% is  $1/19 = 5.3\%$ , the smallest value of PCF or LCF is 71.6% ( $0.7 + 0.3 * 5.3\%$ ), and the maximum achievable diversification credit is 28.4%, ( $100\% - 71.6\%$ ).

### Alternatives to the CoMaxLine% Approach

Looking at the treatment of diversification in regulatory capital formulas developed in other regulatory regimes, the UK Individual Capital Adequacy Standard (UK ICAS) can be thought of as the simplest. In UK ICAS there is no premium or reserve risk diversification adjustment. Instead, LOB risk factors were selected to represent the LOB risk when combined with a typical LOB distribution.<sup>14</sup>

The CoMaxLine% Approach can be viewed as one step more complex than the UK ICAS in that it recognizes different levels of diversification.

From the risk theory perspective, the natural approach to diversification is to combine risk

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<sup>14</sup> Solvency – Models, Assessment and Regulation, Arne Sandström, 2006, Taylor & Francis Group, LLC, p 161-164, <http://docslide.us/documents/solvency-models-assessment-and-regulation.html>;  
Also at NAIC, SMI, Country Comparisons, UK, [http://www.naic.org/documents/committees\\_smi\\_int\\_solvency\\_uk.pdf](http://www.naic.org/documents/committees_smi_int_solvency_uk.pdf)

charges by LOB using correlation<sup>15</sup> factors between each pair of LOBs. Individual company economic capital models (called ‘internal models’ in Solvency II) often use this pairwise correlation matrix approach. The Solvency II Standard Formula uses the pairwise correlation matrix approach. The correlation matrix approach, if applied in the RBC Formula, would require 171 parameters since 19 LOBs are used. In contrast to the correlation matrix 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, as another alternative to CoMaxLine% and correlation matrix approaches, we also consider a 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.<sup>16</sup>

Finally, the Herfindahl-Hirschman Index (HHI) is widely used by economists to measure concentration. HHI considers the relative proportions of all LOBs, the largest, second largest, third largest, and so on.<sup>17</sup> HHI is more complex than the CoMaxLine% Approach in that it recognizes the extent of diversification for the 2<sup>nd</sup>, 3<sup>rd</sup>, 4<sup>th</sup>, etc. largest LOBs.<sup>18</sup> HHI is simpler than the correlation matrix approach in that HHI does not recognize differences in the extent of the diversification between different pairs of LOBs.<sup>19</sup>

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<sup>15</sup> We use the term correlation matrix approach to describe a factor method or copula method for computing total risk by combining several individual risks. In using the term, we do not intend to imply that the assumptions related to linear correlation are appropriate.

<sup>16</sup> For CoMaxLine%-Risk, as for CoMaxLine%, the risk charge after diversification equals the sum of the risk charges over all LOBs times the PCF and LCF determined using the risk version of CoMaxLine% for premium risk and reserve risk, respectively.

<sup>17</sup> 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 the CoMaxLine%. With two lines split 25% and 75% HHI is  $0.25^2$  plus  $0.75^2$  or 0.625 compared to the CoMaxLine% of 0.750, i.e., HHI shows 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, more diversification than the CoMaxLine% of 0.5. With two lines split 50% and 50% HHI and the CoMaxLine% are both 0.5.

<sup>18</sup> 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  $p_1^2 + p_2^2 + p_3^2 \dots + p_n^2$ . The truncated HHI limited to one element would be  $p_1^2$ . CoMaxLine% is  $p_1$ . HHI is always less than or equal to CoMaxLine%.

<sup>19</sup> For HHI, as for CoMaxLine%, the risk charge after diversification equals the sum of the risk charges over all LOBs times the PCF and LCF determined using the HHI formula, separately for premium risk and reserve risk.

### 3. Effect of Alternative Diversification Formulas

We now look at the extent to which the different methods of measuring diversification for  $R_4$  and  $R_5$  produce different RBC UW Risk Values. For each company that filed a 2010 Annual Statement, we calculate the all-lines value for  $R_4$  and for  $R_5$  before diversification using the 2010 RBC Formula.<sup>20</sup> We then use each of the following approaches to calculate the effect of diversification across LOBs, arriving at  $R_4$  and  $R_5$ , after diversification, for each company:

- a. CoMaxLine% based on volume (as applied in the NAIC RBC Formula)
- b. CoMaxLine%-Risk
- c. Correlation matrix
- d. HHI

Using the values of  $R_4$  and  $R_5$ , after diversification, for each company, for each of the four approaches, we calculate the RBC UW Risk Value.<sup>21</sup> Appendix 1 provides more details regarding the data used and the simplifying steps taken in applying the RBC Formula with each of the four diversification approaches.

#### 3.1 Correlation vs. CoMaxLine%

In this section, we compare the results of using the CoMaxLine% Approach (based on volume) to the results of using the correlation matrix approach.

To apply the correlation matrix approach, we construct a set of pairwise correlation factors, called a correlation matrix. Following the Solvency II approach, we use values of 25% or 50% for most of the 171 LOB-pairs.<sup>22</sup> For several LOB-pairs that we consider very highly correlated we select correlation factors of 75% or 100%.<sup>23</sup>

Appendix 1/Exhibit 1 shows our correlation matrix. Appendix 1/Exhibit 2 shows the Solvency II Standard Formula LOB correlation matrix, for comparison.

For each company with a 2010 Annual Statement, we apply both the CoMaxLine% Approach and the correlation matrix approach to produce the two alternative RBC UW Risk Values. The company-by-company differences between the two diversification approaches

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<sup>20</sup> We calculate the Company Action Level of RBC.

<sup>21</sup> We are not testing alternatives to the way that the RBC Formula combines premium risk and reserve risk.

<sup>22</sup> “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 1 for further discussion of the origin of the Solvency II correlation matrix.

<sup>23</sup> 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.

have two parts:

- the overall industry-wide difference, and
- the remaining difference for each individual company after normalizing to remove the industry-wide difference.

We measure the first part by computing the total US industry-wide RBC UW Risk Value that each approach produces, using the 30% MDC in the CoMaxLine% Approach and using the parameters specified in Appendix 1 / Exhibit 1 in the correlation matrix approach. We find that the industry-total RBC UW Risk Value is \$106.2 billion with the CoMaxLine% Approach and \$100.6 billion with the correlation matrix approach. We find that increasing the 30% MDC to 39.1% in the CoMaxLine% Approach decreases the RBC UW Risk Value to \$100.6 billion, equal to the correlation matrix-based RBC UW Risk Value.<sup>24</sup>

In this analysis, we are more interested in the second part, the differences in diversification credit by company that remain after controlling for the overall effect on the total industry-wide RBC UW Risk Value. Therefore, we look at the company-by-company differences between the CoMaxLine% Approach with a MDC of 39.1%, and the correlation matrix approach using the parameters specified in Appendix 1 / Exhibit 1.

Looking at the differences, we observe a sizable number of cases where the UW risk values are the same regardless of the diversification structure. These zero differences arise for companies that have zero UW risk (i.e. due to having zero premium and reserves in all lines) and for mono-line companies.<sup>25,26</sup> We focus on multi-line companies, where the choice of diversification formula can affect the RBC UW Risk Value. The histogram in Table 3-1 below includes multi-line companies only and shows the distribution of percentage differences in RBC UW Risk Values by company.

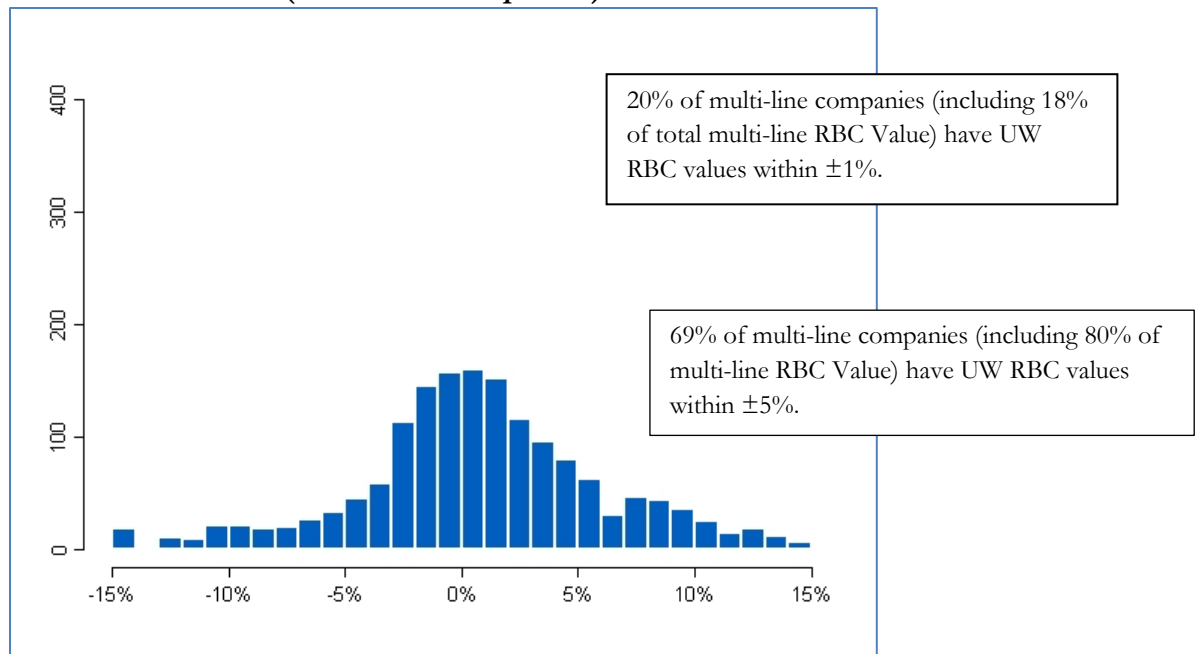
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<sup>24</sup> The CoMaxLine% Approach with a 30% MDC produces approximately the same total RBC as a correlation matrix with all pairwise correlations of 50%. Our selected correlation matrix has correlations at, generally, 50% or 25%. Thus, the average correlation in the matrix is lower than 50%. The resulting diversification is higher than the CoMaxLine% Approach with 30%. Therefore, an equivalent CoMaxLine% formula would need a MDC greater than 30%, as is the case.

<sup>25</sup> Including some companies that are so close to mono-line that the effect rounds to zero within \$1k.

<sup>26</sup> We also remove some companies with significant negative premiums/reserves that would distort the comparisons among diversification methods.

**Table 3-1**  
**2010 RBC UW Risk Value Differences by Company<sup>27</sup>**  
**Distribution of Number of Companies**  
**Correlation matrix approach versus CoMaxLine% Approach (39.1% MDC)**  
**(Multi-line Companies)**



X-axis = Percentage difference between RBC UW Risk Values based on CoMaxLine% Approach and RBC UW Risk Values based on correlation matrix approach.  
 Y-axis = Number of companies, in buckets of 1% difference in RBC UW Risk Value.

We find that:

- For 33% of companies, with 3% of total industry-wide RBC UW Risk Value, the difference between diversification approaches is zero because they have zero UW risk (14.8%) or because they are mono-line (18.6%). These companies are excluded from the histogram.
- For 20% of the multi-line companies, with 18% of the industry-wide multi-line RBC UW Risk Value, the differences are less than  $\pm 1\%$ .
- For 69% of the multi-line companies, with 80% of the industry-wide multi-line RBC UW Risk Value, the differences are less than  $\pm 5\%$ .
- The differences are greater than 10% for only 10% of the multi-line companies constituting about 9% of the industry-wide multi-line RBC UW Risk Value.

<sup>27</sup> Positive differences represent companies for which the correlation matrix approach produces a higher RBC UW Risk Value than the CoMaxLine% Approach.



- Considering all companies, even those companies which are mono-line, or which have zero premium and reserves, we find that for 46% of all companies, with 20% of the total RBC UW Risk Value, the differences are less than  $\pm 1\%$ . For 79% of all companies, with 79% of the total RBC UW Risk Value, the differences are less than  $\pm 5\%$ .

Differences of 5% might be considered small as a practical matter. In addition, we consider the differences to be small for several statistical reasons. First, the differences are not large compared to the inherent accuracy of the risk factors which are used to calculate  $R_4$  and  $R_5$  for each individual LOB. Moreover, the systematic variation in LOB risk factors due to LOB-size, LOB-age, and other factors discussed in DCWP Reports 6-9 is larger than the variation shown here from using a different diversification approach. Finally, correlation matrix values have inherent uncertainty, particularly in that the values are largely calibrated by expert judgment with only limited data.

### **3.2 Correlation Matrix versus CoMaxLine<sup>0</sup>-Risk**

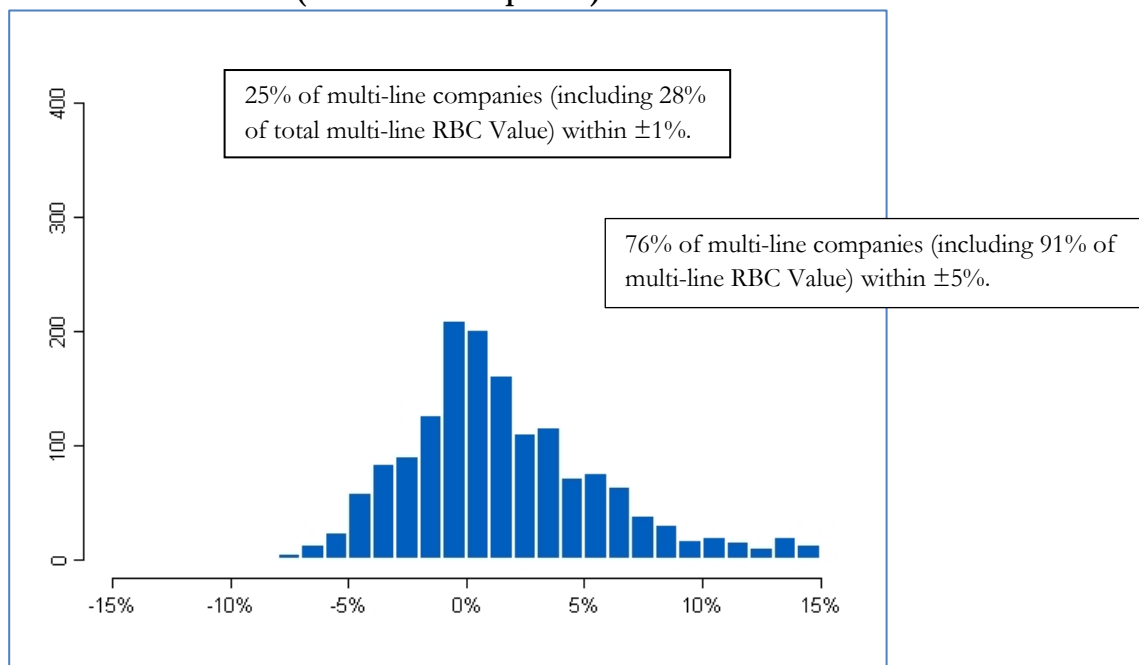
The difference between the correlation matrix approach and the CoMaxLine<sup>0</sup> Approach is due, in part, to the fact that the degree of diversification in the correlation matrix approach is based on risk by LOB while the degree of diversification in the CoMaxLine<sup>0</sup> Approach is based on volume (premium amount or reserve amount) by LOB.

In this section we evaluate the effect of that difference by comparing CoMaxLine<sup>0</sup>-Risk to the correlation matrix approach, company-by-company.

First, to calibrate the CoMaxLine<sup>0</sup>-Risk approach, we determine that with a MDC of 44.4% the industry-wide RBC UW Risk Value produced by CoMaxLine<sup>0</sup>-Risk is the same as the total industry-wide RBC UW Risk value from the correlation matrix approach (\$100.6 billion). Then, as we did with the NAIC CoMaxLine<sup>0</sup> Approach, we examine the company-by-company differences between CoMaxLine<sup>0</sup>-Risk and the correlation matrix approach that remain when both produce the same total industry-wide RBC UW Risk Value.

The histogram in Table 3-2, below, shows the distribution of differences, company-by-company, in the same format as Table 3-1. As was the case in Table 3-1, Table 3-2 excludes mono-line companies and companies with zero RBC UW Risk Values.

**Table 3-2**  
**2010 RBC UW Risk Value Differences by Company<sup>28</sup>**  
**Distribution of Number of Companies**  
**Correlation matrix approach versus CoMaxLine%-Risk Approach (44.4% MDC)**  
**(Multi-line Companies)**



X-axis = Percentage difference between RBC UW Risk Values based on CoMaxLine%-Risk Approach and RBC UW Risk Values based on correlation matrix approach.  
 Y-axis = Number of companies, in buckets of 1% difference in RBC UW Risk Value.

Comparing Table 3-1 and Table 3-2 we see that the percentage of multi-line companies with CoMaxLine%-Risk within 5% of the correlation matrix approach is 76%, 7 percentage points more than with the CoMaxLine% Approach. Also, the percentage of RBC UW Risk Value of multi-line companies with CoMaxLine%-Risk within 10% of the correlation matrix approach is 93%, 3 percentage points more than with the CoMaxline% approach.

### 3.3 HHI vs. CoMaxLine%

In this section, we compare the results of using the CoMaxLine% Approach to the results of using the HHI approach. In Appendix 1, we describe how we calculate the RBC UW Risk Values using the HHI approach.

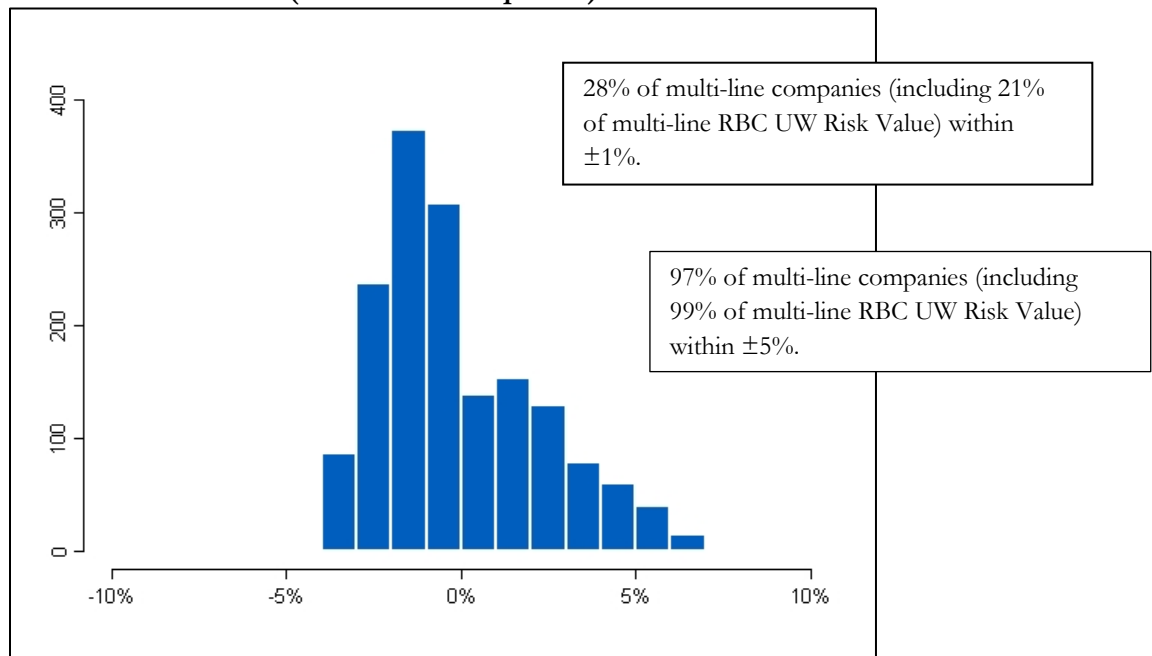
<sup>28</sup> Positive differences represent companies for which the correlation matrix approach produces a higher RBC UW Risk Value than the CoMaxLine%-Risk Approach.

For each company with a 2010 Annual Statement, we apply both the CoMaxLine% Approach and the HHI approach to produce the RBC UW Risk Values by company. Similar to the discussion in Section 3.1, the differences company-by-company between the two diversification approaches have two parts, and we are interested in the differences that remain after controlling for the overall difference in the industry-wide RBC UW Risk Values. We again focus on the companies with non-zero differences in RBC UW Risk Values.

The industry-wide RBC UW Risk Value produced by the HHI approach, with a MDC of 30%, is \$101.5 billion. The industry-wide RBC UW Risk Value produced by the CoMaxLine% Approach would be \$101.5 billion if the MDC were increased from 30% to 37.7%.

The histogram in Table 3-3, below, shows the distribution of differences, company-by-company, in the same format as Tables 3-1 and 3-2. As was the case in those tables, Table 3-3 excludes mono-line companies and companies with zero RBC UW Risk Values.

**Table 3-3**  
**2010 RBC UW Risk Value Differences by Company**  
**Distribution of Number of Companies**  
**HHI approach versus CoMaxLine% Approach (37.7% MDC)**  
**(Multi-Line companies)**



X-axis = Percentage difference between RBC UW Risk Values based on CoMaxLine% Approach and RBC UW Risk Values based on HHI approach.  
 Y-axis = Number of companies, in buckets of 1% difference in RBC UW Risk Value.

We find that:

- 33% of all companies are excluded from the histogram because they are not multi-line.
- For 28% of the multi-line companies, with 21% of the industry-wide multi-line RBC UW Risk Value, the differences are less than  $\pm 1\%$ .
- For 97% of the multi-line companies, with 99% of the industry-wide RBC UW Risk Value, the differences are less than  $\pm 5\%$ .
- There are no companies where the differences are greater than 10%.
- Considering all companies, even those companies which are mono-line, or which have zero premium and reserves, we find that for 52% of all companies, with 23% of the total RBC UW Risk Value, the differences are less than  $\pm 1\%$ . For 97% of all companies, with 99% of the total RBC UW Risk Value, the differences are less than  $\pm 5\%$ .

### 3.4 Further Observations

An analysis of why the three methods discussed in this report produce similar results is beyond the scope of this paper. However, in this section we discuss some of the factors that contribute to that result.

First, the diversification credits are zero for mono-line companies, regardless of method.

Second, the correlation matrix values for LOB-pairs are not highly varied. It is possible that the differences would be wider if the correlation matrix values were more varied, but we have not explored that possibility.

Third, the diversification element is only one part of the RBC UW Risk Value. The dollar weighted average diversification credit for all multi-line companies is 20%.<sup>29</sup> Differences in diversification credit are thus “diluted” in the total calculation. For multi-line companies with little diversification credit, even large percentage differences in diversification credit have a small effect on total RBC UW Risk Value.

Finally, the diversification formula has the greatest effect on the most diversified companies, and we find that the differences between the CoMaxLine% Approach and the correlation matrix approach decrease as company diversification increases.<sup>30</sup>

Appendix 2, Exhibit 3, Box A, shows the RBC UW Risk Value, the dollars of diversification

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<sup>29</sup> Appendix 2/Exhibit 3/Box A/Column “All”.

<sup>30</sup> Appendix 2/Exhibit 4/Box D/trend in columns from least diversified to most diversified/in rows -5 to +5, -10 to +10 and -25 to +25.

credit and the average diversification credit for all companies combined and for companies within each company diversification band. Box B shows the same information by RBC UW Risk Value. Boxes C and D show the corresponding information based on the CoMaxLine%-Risk measure of diversification.

In Appendix 2, Exhibit 4 we show the proportions of companies where UW Risk RBC Values varies by 5% or less, 10% or less and 25% or less, for the CoMaxLine% Approach versus the correlation matrix approach, by company size band (measured by RBC UW Risk Value) and by company diversification band. In Appendix 2, Exhibit 4 we also show the proportion of companies where the dollar diversification amount varies by 5% or less, 10% or less and 25% or less, for the CoMaxLine% Approach versus correlation matrix approach, by company size band (measured by RBC UW Risk Value) and by diversification band.

We say the CoMaxLine% Approach is closer to the correlation matrix approach for size/diversification cells where the proportion of companies within the 5% variation, 10% variation and 25% variation bands is higher. We see that RBC UW Risk Value from the CoMaxLine% Approach is closer to the correlation matrix approach for the larger companies (Box C) and for the more diversified companies (Box D).

In Appendix 2, Exhibit 5 we show the data for CoMaxLine%-Risk versus the correlation matrix approach as we did in Exhibit 4 for CoMaxLine% versus the correlation matrix approach. We see that CoMaxLine%-Risk is generally closer to the correlation matrix approach than was the case for the CoMaxLine% Approach.

#### 4. 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 across LOBs. It is $(1.0 - \text{CoMaxLine}\%)$ times 30%.   |
| CoMaxLine%-Risk Approach              | CoMaxLine% Approach based on risk charge size by LOB rather than premium or reserve volume by LOB.   |
| Correlation                           | We use that term to characterize methods of combining LOB risk charges to produce an all-lines risk charge or combining premium risk and reserve risk to produce total risk using 'correlation factors.'<br><br>The 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.<br><br>The use of the term does not imply that the assumptions underlying individual and joint distributions of the parameters are satisfied.  |
| Correlation Matrix                    | A matrix of correlation factors, typically one factor for each pair of LOBs.   |
| DCWP                                  | Risk-Based Capital Dependency and Calibration Working Party of the Casualty Actuarial Society  |
| LCF                                   | Loss Concentration Factor, as calculated in the 2010 RBC Formula, applicable to reserve risk.<br>Based on the 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 income 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 | For each company and LOB, premium risk and reserve risk are based 50% on factors calibrated on industry data and 50% on industry data adjusted by the ratio of company experience to industry experience for the most recent 10 years (if 10 years of company data is available, otherwise, there is no adjustment).                                   |
| PCF                                   | Premium Concentration Factor as calculated in the 2010 RBC Formula.<br>Based on the CoMaxLine% Approach.   |
| R <sub>0</sub>                        | Asset Risk – Insurance affiliate investment and (non-derivative) off-balance sheet risk.   |
| R <sub>1</sub>                        | Asset Risk – Fixed Income Investments  |
| R <sub>2</sub>                        | Asset Risk – Equity  |

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|   |  |
|---|--|
| R <sub>3</sub>                          | Credit risk (non-reinsurance plus one half of Reinsurance Credit Risk)   |
| R <sub>3</sub> -Reinsurance Credit Risk | See Reinsurance Credit Risk  |
| R <sub>4</sub>                          | UW – Reserve risk plus one half of reinsurance credit risk, <sup>31</sup> including growth risk.<br>This paper uses R <sub>4</sub> without the reinsurance credit risk adjustment and without growth risk.         |
| R <sub>5</sub>                          | UW – Premium risk, including growth risk.<br>This paper uses R <sub>5</sub> without growth risk.   |
| RBC                                     | Risk-Based Capital   |
| RBC Formula or Formula                  | The 2010 NAIC Property-Casualty RBC Formula  |
| RBC Value                               | The Company Action Level amount calculated from the RBC Formula.   |
| RBC UW Risk Value                       | The Company Action Level amount calculated for the UW risk components of the RBC Formula.  |
| Reinsurance Credit Risk                 | An element of R <sub>3</sub> , representing both credit risks related to reinsurance financial capacity and the difference in premium and reserve risk between companies with varying levels of ceded reinsurance. |
| 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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<sup>31</sup> The ‘transfer’ from credit risk to reserve risk applies only if the pure reserve risk component is larger than the reinsurance credit risk, as is the case for most companies.

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## Appendix 1 - Calculation of 2010 RBC UW Risk Values by Company

In Section 3, we compare the RBC UW Risk Values from the RBC Formula with the RBC UW Risk Values from alternative formulas in which we replace the CoMaxLine% calculation with correlation matrix, CoMaxLine%-Risk and HHI calculations. We use 2010 Annual Statement data by company<sup>32</sup> to determine the company-by-company RBC UW Risk Values as described below.

For each LOB individually:

- We obtain 2010 net written premium and net loss and loss adjustment expense reserves by LOB from the Annual Statement.
- We use Schedule P Part 2 reserve runoff to calculate the own-company adjustment factors for reserve risk.
- We use Schedule P Part 1 LRs to calculate the own-company adjustment factors for premium risk.
- We use Schedule P Parts 7A and 7B to calculate the loss-sensitive contract adjustment for premium risk.
- For each LOB, we apply the premium risk factor, the reserve risk factor, the premium and reserve investment income offsets, the own company adjustments, and loss sensitive contract adjustment, in accordance with the 2010 RBC Formula.

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<sup>32</sup> For this purpose, we considered individual company legal entities. We do not use the NAIC groups or DCWP-pooled companies.

- The premium calculation includes extra steps in that premium risk factors by LOB are converted to the premium risk charge by LOB using the all-lines company expense ratio.

#### All LOBs combined

- We determine the all-lines combined risk values for premium and reserves using the PCFs and LCFs by company, respectively.  
As explained in Section 2, for each company, the PCFs and LCFs will be values between 71.6% and 100.0% using the CoMaxLine% Approach.

#### Simplifications

- We do not apply the growth risk charge
- We do not apply the own-company adjustment for 2-Year LOBs, as the necessary data is not in Schedule P.
- The reserve risk component does not include the R<sub>3</sub>-Reinsurance Credit Risk amount that is transferred to R<sub>4</sub>.

#### Correlation Matrix Approach

To estimate the RBC UW Risk Values for the correlation matrix approach we first calculate the results by LOB as described above, using all-lines company expenses for each LOB.<sup>33</sup>

We combine the LOB risk charges applying correlation matrix, Appendix 6A/Exhibit 6-1<sup>34</sup> to the risk charges by LOB.

#### CoMaxLine%-Risk Approach

To estimate the RBC UW Risk Values for the CoMaxLine%-Risk Approach we first calculate the premium risk and reserve risk values by LOB in accordance with RBC Formula as described above for the correlation matrix approach.

We calculate CoMaxLine%-Risk using the dollar amounts of premium risk and reserve risk, by LOB, rather than using the dollar amounts of premium and reserves.

We calculate the PCFs/LCFs from the CoMaxLine%-Risk.

#### HHI Alternative

To estimate the RBC UW Risk Values for the HHI approach we first calculate the results by LOB as described above.

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<sup>33</sup> When the RBC Formula was constructed it was decided to use company total expenses rather than LOB expenses in the premium UW risk calculation because the LOB expenses are not available in the Annual Statement. The expenses by LOB are produced one month later in the Insurance Expense Exhibit.

<sup>34</sup> In mathematical terms, we take the LOB risk charges as a 19x1 vector; multiply it by the 19x19 correlation matrix and multiple that by the LOB risk charges, in dollars, as a 1x19 vector. LCF and PCF factors are not used in the correlation matrix approach.

We calculate the PCFs/LCFs using the HHI values rather than CoMaxLine%. The HHI concentration value 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.

To combine the LOBs, we replace the CoMaxLine%s with the HHI values.

- For each LOB, we apply the premium risk factor, the reserve risk factor, the premium and reserve investment income offsets, the own company adjustments, and loss sensitive contract adjustment, in accordance with the 2010 RBC Formula.

#### Company Selection

There are 2,434 companies with 2010 Annual Statements in our data set. Of those, 50 companies have significantly negative premium or reserves for some LOBs.<sup>35</sup> The RBC Formula substitutes zero for negative values. For our work, we eliminate those 50 companies, leaving 2,384 companies in our analysis. Of those, 360 have zero UW Risk RBC and 402 have zero diversification credit in the CoMaxLine%, CoMaxLine%-Risk and HHI calculations. The remaining 1,622 companies provide information on how the diversification formulas affect RBC UW Risk Values.

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<sup>35</sup> Negative in total for all lines combined or with large enough negative values to potentially distort one or more of the diversification formulas we are testing.

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Appendix 1/Exhibit 1

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

| LOB/LOB         | HO         | PPA        | CA         | WC   | CMP  | M-Occ       | M-CM        | SL          | OL          | SP         | Phy        | Fid  | Other | Int'l | Re Prop | Re- Liab | Prod        | FG   | Warranty |
|-----------------|------------|------------|------------|------|------|-------------|-------------|-------------|-------------|------------|------------|------|-------|-------|---------|----------|-------------|------|----------|
| <b>HO</b>       | 100%       | 25%        | 25%        | 25%  | 50%  | 25%         | 25%         | 25%         | 25%         | <b>75%</b> | 50%        | 25%  | 25%   | 25%   | 25%     | 25%      | 25%         | 25%  | 25%      |
| <b>PPA</b>      | 25%        | 100%       | 50%        | 25%  | 25%  | 25%         | 25%         | 25%         | 25%         | 25%        | <b>75%</b> | 25%  | 25%   | 25%   | 25%     | 25%      | 25%         | 25%  | 25%      |
| <b>CA</b>       | 25%        | 50%        | 100%       | 50%  | 50%  | 25%         | 25%         | 50%         | 50%         | 25%        | <b>75%</b> | 25%  | 25%   | 25%   | 25%     | 25%      | 50%         | 25%  | 25%      |
| <b>WC</b>       | 25%        | 25%        | 50%        | 100% | 25%  | 25%         | 25%         | 25%         | 25%         | 25%        | 25%        | 25%  | 25%   | 25%   | 25%     | 25%      | 25%         | 25%  | 25%      |
| <b>CMP</b>      | 50%        | 25%        | 50%        | 25%  | 100% | 25%         | 25%         | 50%         | 50%         | 50%        | 25%        | 25%  | 25%   | 25%   | 25%     | 25%      | 50%         | 25%  | 25%      |
| <b>M-Occ</b>    | 25%        | 25%        | 25%        | 25%  | 25%  | 100%        | <b>100%</b> | 50%         | 50%         | 25%        | 25%        | 25%  | 25%   | 25%   | 25%     | 25%      | 50%         | 25%  | 25%      |
| <b>M-CM</b>     | 25%        | 25%        | 25%        | 25%  | 25%  | <b>100%</b> | 100%        | 50%         | 50%         | 25%        | 25%        | 25%  | 25%   | 25%   | 25%     | 25%      | 50%         | 25%  | 25%      |
| <b>SL</b>       | 25%        | 25%        | 50%        | 25%  | 50%  | 50%         | 50%         | 100%        | <b>75%</b>  | 25%        | 25%        | 25%  | 25%   | 25%   | 25%     | 50%      | <b>100%</b> | 25%  | 25%      |
| <b>OL</b>       | 25%        | 25%        | 50%        | 25%  | 50%  | 50%         | 50%         | <b>75%</b>  | 100%        | 25%        | 50%        | 50%  | 25%   | 50%   | 25%     | 50%      | <b>100%</b> | 25%  | 25%      |
| <b>SP</b>       | <b>75%</b> | 25%        | 25%        | 25%  | 50%  | 25%         | 25%         | 25%         | 25%         | 100%       | 25%        | 25%  | 25%   | 25%   | 50%     | 25%      | 25%         | 25%  | 25%      |
| <b>Phy</b>      | 50%        | <b>75%</b> | <b>75%</b> | 25%  | 25%  | 25%         | 25%         | 25%         | 50%         | 25%        | 100%       | 25%  | 25%   | 25%   | 25%     | 25%      | 25%         | 25%  | 25%      |
| <b>Fid</b>      | 25%        | 25%        | 25%        | 25%  | 25%  | 25%         | 25%         | 25%         | 50%         | 25%        | 25%        | 100% | 25%   | 25%   | 25%     | 50%      | 25%         | 25%  | 25%      |
| <b>Other</b>    | 25%        | 25%        | 25%        | 25%  | 25%  | 25%         | 25%         | 25%         | 25%         | 25%        | 25%        | 100% | 25%   | 25%   | 25%     | 25%      | 25%         | 25%  | 25%      |
| <b>Int'l</b>    | 25%        | 25%        | 25%        | 25%  | 25%  | 25%         | 25%         | 25%         | 50%         | 25%        | 25%        | 25%  | 100%  | 25%   | 25%     | 25%      | 25%         | 25%  | 25%      |
| <b>Re Prop</b>  | 25%        | 25%        | 25%        | 25%  | 25%  | 25%         | 25%         | 25%         | 25%         | 50%        | 25%        | 25%  | 25%   | 25%   | 100%    | 25%      | 25%         | 25%  | 25%      |
| <b>Re- Liab</b> | 25%        | 25%        | 25%        | 25%  | 25%  | 25%         | 25%         | 50%         | 50%         | 25%        | 25%        | 50%  | 25%   | 25%   | 25%     | 100%     | 50%         | 25%  | 25%      |
| <b>Prod</b>     | 25%        | 25%        | 50%        | 25%  | 50%  | 50%         | 50%         | <b>100%</b> | <b>100%</b> | 25%        | 25%        | 25%  | 25%   | 25%   | 25%     | 50%      | 100%        | 25%  | 25%      |
| <b>FG</b>       | 25%        | 25%        | 25%        | 25%  | 25%  | 25%         | 25%         | 25%         | 25%         | 25%        | 25%        | 25%  | 25%   | 25%   | 25%     | 25%      | 25%         | 100% | 25%      |
| <b>Warranty</b> | 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                 | Int'l        |
| 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/Mortgage Guarantee  | FG           |
| Medical Prof Liab - Occ | M-Occ        | Other                 | Other        | Warranty                      | Warranty     |
| Medical Prof Liab - CM  | M-CM         |                       |              |                               |              |



Solvency II Correlation Matrix

The Solvency II Standard Formula uses a correlation matrix to specify LOB diversification. Appendix 1/Exhibit 2A lists the Solvency II 12 non-life LOBs

**Appendix 1/Exhibit 2A Solvency II LOBs<sup>36</sup>**

|   |                                   |    |   |
|---|-----------------------------------|----|---|
| 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

Appendix 1/Exhibit 2B below shows the Solvency II Standard Formula LOB correlation matrix for those 12 LOBs.<sup>37</sup>

**Appendix 1/Exhibit 2B  
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% |

The factors equal to 1.0, along the diagonal, represent the correlation between the LOB and itself. In the Solvency II 3<sup>rd</sup> Quantitative Impact Analysis (QIS3), the factors were calibrated with data from one country, supplemented by expert judgment. The factors appear to primarily represent an expert judgment on whether the LOB pairwise correlation is lower (0.25) or higher (0.50).

In the Solvency II 4<sup>th</sup> Quantitative Impact Analysis (QIS4) analysis, the factors were sensitivity

<sup>36</sup>

[http://www.lloyds.com/~media/files/the%20market/operating%20at%20lloyds/solvency%20ii/2016%20guidance/2015\\_yesf\\_synd\\_v62.xlsx](http://www.lloyds.com/~media/files/the%20market/operating%20at%20lloyds/solvency%20ii/2016%20guidance/2015_yesf_synd_v62.xlsx). “Non-Life & NSLT Health P&R”

<sup>37</sup> Ibid. Tab “Non-Life and Health UW Risk”

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.<sup>38</sup> 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”*.<sup>39</sup> Thus, the overall level appears to rely heavily on expert judgment much like the 30% MDC in the RBC Formula.

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<sup>38</sup> CEIOPS-DOC-70/10, Annex B, pages 38-44

<sup>39</sup> CEIOPS-DOC-70/10 (Page 44, paragraph B.31)

## Appendix 2 – Comparisons between CoMaxLine%, CoMaxLine%- Risk, and Correlation Matrix Approaches

### Appendix 2/Exhibit 3

Appendix 2/Exhibit 3, below, shows the dollar amount of RBC UW Risk Value, the dollar amount of diversification credit, and the average diversification credit by company-size and by company-diversification band, separately for the CoMaxLine% Approach and the CoMaxLine%-Risk Approach. We define the size and diversification bands below.

#### RBC UW Risk Value Size Bands

We show the data, in seven company-size bands. The bands A through E divide the 1,622 multi-line companies into five groups with approximately 325 companies in each band. Band A has the smallest 20% of multi-line companies. Band E has the largest 20% of multi-line companies. In addition, we show two other informational bands. “Tiny” is for the 75 smallest multi-line companies. This column is for information only, as we include the 75 in band A. “Jumbo” is for the 75 largest multi-line companies. This column is for information, as we include the 75 in band E.

#### Columns: %Diversification Size Bands

We show the data, in seven company-diversification bands. The bands A through E divide the 1,622 multi-line companies into five groups with approximate 325 multi-line companies in each band. Band A has the least diversified multi-line companies, those with the lowest percentage diversification credits. Band E has the most diversified 20% of multi-line companies, those with the highest percentage diversification credits. In addition, we show two other bands. The column “75 Least Diversified” is for the 75 multi-line companies with the lowest, non-zero, diversification percentages. This column is for information as we include the 75 in band A. The column “75 Most Diversified” is for the 75 multi-line companies with the largest diversification credit %. This column is also for information, as we include the 75 in band E.

#### Distribution of RBC UW Risk Value and Diversification Amount

Appendix 2/Exhibit 3, has four “boxes,” labeled A, B, C and D. Within each box we show the dollar amount of RBC UW Risk Value, the percentage of RBC UW Risk Value by size band or diversification band, the dollar amount of diversification credit and the average diversification credit.

Boxes A and C show the data in company-diversification bands, for CoMaxLine% and CoMaxLine%-Risk approaches, respectively. Boxes B and D show the data in RBC UW Risk Size bands, for CoMaxLine% and CoMaxLine%-Risk approaches, respectively.

Some key features of the summary are the following:

- The weighted average percentage diversification across all multi-line companies is 20%, for both the CoMaxLine% Approach and the CoMaxLine%-Risk Approach (the same value appears in boxes A, B, C, and D in the “All” column).

- For the 75 most diversified multi-line companies, the average diversification percentage is 30% for CoMaxLine% (Box A), and 32% for CoMaxLine%-Risk (Box C).
- For CoMaxLine%, the total RBC UW Risk Value is \$97,975 million, excluding mono-line companies. Of that amount, \$64,659 million, or 66%, relates to the 75 largest multi-line companies. \$87,567 million of that amount, or 89%, relates to the largest 20% of multi-line companies (Box B. RBC UW Risk Size Bands/Column E).
- For CoMaxLine%, the total RBC UW Risk Value is essentially the same as for CoMaxLine%-Risk because we calibrated the CoMaxLine% MDC to achieve that result. The distribution by RBC UW Value size bands for CoMaxLine%-Risk is similar to the distribution for CoMaxLine%.
- For CoMaxLine%, nearly all of the diversification credit, \$22 million of \$24 million, arises from size band E, the 20% largest companies by RBC UW Risk Value (Box B/Column E).

### **Appendix 2/Exhibit 4 – CoMaxline% and Correlation Matrix by Size and Diversification Bands**

In Appendix 2/Exhibit 4, we compare RBC UW Risk Value and dollar diversification credit amounts for the CoMaxLine% Approach to the corresponding values for the correlation matrix approach. We show the information for all companies, and separately in size and diversification bands, defined above.

In each column, we show the percentage of multi-line companies with percentage difference in RBC UW Risk Value (Boxes A and B) and percentage difference in dollar diversification credit (Boxes C and D) in bands  $\pm 5\%$ ,  $\pm 10\%$ , and  $\pm 25\%$ , for CoMaxline% versus correlation matrix approaches. Boxes A and C show the information by RBC WW Risk Value Size Band. Boxes B and D show the information by % Diversification Band.

Appendix 2/Exhibit 4/Box A/Column “All” shows that the RBC UW Risk Values differ from the corresponding correlation matrix values by more than 5% for only 31% of all multi-line companies and for 26%, of the largest 20% of multi-line companies (Box A/column E). The values differ by more than 10% for 10% of multi-line companies overall and for 9% of the largest 20% of multi-line companies. (Box A, columns “All” and “E”).

The percentage differences in diversification will be larger than the percentage difference in RBC UW Risk Value. Therefore, the differences in diversification amount will be higher than the differences in RBC UW Risk Values. In fact, the percentage difference in diversification amount is more than 5% for 86% of multi-line companies, more than 10% for 71% of multi-line companies and more than 25% for 48% of multi-line companies (Box C or D/column “All”).

For the most diversified multi-line companies, band E, that are potentially the most affected by differences in the diversification formula, the percentage change in dollars of diversification is more

than 5% for 66% of multi-line companies, but more than 10% for only 28% of multi-line companies and more than 25% for only 6% of multi-line companies; much fewer than for all multi-line companies combined. For the least diversified multi-line companies, band A, the difference in dollars of diversification is greater than 25% for 83% of multi-line companies (Box D), but in that case, the average diversification percentage is only 3% (Exhibit 3/Box A).

### **Appendix 2/Exhibit 5- CoMaxLine%-Risk and Correlation Matrix by Size and Diversification Bands**

Appendix 2/Exhibit 5 compares CoMaxLine%-Risk to the correlation matrix approach, showing the same information as Exhibit 4.

In many respects, the patterns in Exhibit 5 are similar to the patterns in Exhibit 4, but the CoMaxLine%-Risk and correlation matrix approaches are closer than is the case for the CoMaxLine% Approach versus the correlation matrix approach.

**Appendix 2/Exhibit 3  
CoMaxLine% and CoMaxLine%-Risk  
RBC UW Risk Values and Diversification Amounts**

| <b>CoMaxLine%</b>                          |            |                                    |          |          |          |          |          |                                   |
|--|------------|------------------------------------|----------|----------|----------|----------|----------|-----------------------------------|
| <b>A. Percentage Diversification Bands</b> |            |                                    |          |          |          |          |          |                                   |
| <b>Item</b>                                | <b>All</b> | <b>75 Least Diversified (memo)</b> | <b>A</b> | <b>B</b> | <b>C</b> | <b>D</b> | <b>E</b> | <b>75 Most Diversified (memo)</b> |
| RBC UW Risk Value                          | 97,975     | 956                                | 5,249    | 15,939   | 19,364   | 30,805   | 26,617   | 4,274                             |
| % of RBC UW Risk Value                     | 100%       | 1%                                 | 5%       | 16%      | 20%      | 31%      | 27%      | 4%                                |
| \$ of Diversification                      | 23,901     | 3                                  | 141      | 1,747    | 3,702    | 8,618    | 9,693    | 1,819                             |
| Avg % Diversification                      | 20%        | 0%                                 | 3%       | 10%      | 16%      | 22%      | 27%      | 30%                               |
| <b>B. RBC UW Risk Size Bands</b>           |            |                                    |          |          |          |          |          |                                   |
| <b>Item</b>                                | <b>All</b> | <b>Tiny (memo)</b>                 | <b>A</b> | <b>B</b> | <b>C</b> | <b>D</b> | <b>E</b> | <b>Jumbo (memo)</b>               |
| RBC UW Risk Value                          | 97,975     | 8                                  | 218      | 928      | 2,523    | 6,739    | 87,567   | 64,659                            |
| % of RBC UW Risk Value                     | 100%       | 0%                                 | 0%       | 1%       | 3%       | 7%       | 89%      | 66.0%                             |
| \$ of Diversification                      | 23,901     | 1                                  | 33       | 163      | 480      | 1,364    | 21,861   | 16,354                            |
| Avg % Diversification                      | 20%        | 12%                                | 13%      | 15%      | 16%      | 17%      | 20%      | 20%                               |

| <b>CoMaxLine% - Risk</b>                   |            |                                    |          |          |          |          |          |                                   |
|--|------------|------------------------------------|----------|----------|----------|----------|----------|-----------------------------------|
| <b>C. Percentage Diversification Bands</b> |            |                                    |          |          |          |          |          |                                   |
| <b>Item</b>                                | <b>All</b> | <b>75 Least Diversified (memo)</b> | <b>A</b> | <b>B</b> | <b>C</b> | <b>D</b> | <b>E</b> | <b>75 Most Diversified (memo)</b> |
| RBC UW Risk Value                          | 97,990     | 691                                | 7,297    | 17,477   | 26,467   | 21,652   | 25,097   | 4,864                             |
| % of RBC UW Risk Value                     | 100%       | 1%                                 | 7%       | 18%      | 27%      | 22%      | 26%      | 5%                                |
| \$ of Diversification                      | 23,886     | 2                                  | 243      | 1,907    | 4,798    | 6,405    | 10,533   | 2,296                             |
| Avg % Diversification                      | 20%        | 0%                                 | 3%       | 10%      | 15%      | 23%      | 30%      | 32%                               |
| <b>D. RBC UW Risk Size Bands</b>           |            |                                    |          |          |          |          |          |                                   |
| <b>Item</b>                                | <b>All</b> | <b>Tiny (memo)</b>                 | <b>A</b> | <b>B</b> | <b>C</b> | <b>D</b> | <b>E</b> | <b>Jumbo (memo)</b>               |
| RBC UW Risk Value                          | 97,990     | 8                                  | 215      | 921      | 2,490    | 6,661    | 87,703   | 65,120                            |
| % of RBC UW Risk Value                     | 100%       | 0%                                 | 0%       | 1%       | 3%       | 7%       | 90%      | 66%                               |
| \$ of Diversification                      | 23,886     | 1                                  | 37       | 168      | 522      | 1,455    | 21,703   | 15,794                            |
| Avg % Diversification                      | 20%        | 13%                                | 15%      | 15%      | 17%      | 18%      | 20%      | 20%                               |

**Appendix 2/Exhibit 4**

**% Difference from CoMaxLine<sup>o</sup> Approach to Correlation Matrix Approach**

| <b>A. Change in RBC UW Risk Value by RBC UW Risk Value Size Band</b> |                        |             |      |      |      |      |      |              |
|--|------------------------|-------------|------|------|------|------|------|--------------|
| % Change in RBC UW Risk Value  | RBC UW Risk Size Bands |             |      |      |      |      |      |              |
|  | All                    | Tiny (memo) | A    | B    | C    | D    | E    | Jumbo (memo) |
| -5 to +5   | 69%                    | 51%         | 64%  | 64%  | 67%  | 77%  | 74%  | 81%          |
| -10 to +10   | 90%                    | 89%         | 88%  | 88%  | 89%  | 95%  | 91%  | 91%          |
| -25 to +25   | 100%                   | 100%        | 100% | 100% | 100% | 100% | 100% | 100%         |

|                   |     |     |     |     |     |     |     |     |
|-------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Greater than ±5%  | 31% | 49% | 36% | 36% | 33% | 23% | 26% | 19% |
| Greater than ±10% | 10% | 11% | 12% | 12% | 11% | 5%  | 9%  | 9%  |
| Greater than ±25% | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  |

| <b>B. Change in RBC UW Risk Value by % Diversification Band</b> |                                  |                             |      |      |      |      |      |                            |
|---|----------------------------------|-----------------------------|------|------|------|------|------|----------------------------|
| % Change in RBC UW Risk Value                                   | Percentage Diversification Bands |                             |      |      |      |      |      |                            |
|   | All                              | 75 Least Diversified (memo) | A    | B    | C    | D    | E    | 75 Most Diversified (memo) |
| -5 to +5  | 69%                              | 99%                         | 96%  | 59%  | 53%  | 60%  | 78%  | 84%                        |
| -10 to +10  | 90%                              | 99%                         | 98%  | 94%  | 82%  | 79%  | 97%  | 93%                        |
| -25 to +25  | 100%                             | 100%                        | 100% | 100% | 100% | 100% | 100% | 100%                       |

|                   |     |    |    |     |     |     |     |     |
|-------------------|-----|----|----|-----|-----|-----|-----|-----|
| Greater than ±5%  | 31% | 1% | 4% | 41% | 47% | 40% | 22% | 16% |
| Greater than ±10% | 10% | 1% | 2% | 6%  | 18% | 21% | 3%  | 7%  |
| Greater than ±25% | 0%  | 0% | 0% | 0%  | 0%  | 0%  | 0%  | 0%  |

| <b>C. Change in \$ Diversification by RBC UW Risk Value Size Band</b> |                        |             |     |     |     |     |     |              |
|---|------------------------|-------------|-----|-----|-----|-----|-----|--------------|
| % Change in Div \$  | RBC UW Risk Size Bands |             |     |     |     |     |     |              |
|   | All                    | Tiny (memo) | A   | B   | C   | D   | E   | Jumbo (memo) |
| -5 to +5  | 14%                    | 4%          | 7%  | 12% | 15% | 19% | 18% | 20%          |
| -10 to +10  | 29%                    | 9%          | 16% | 20% | 26% | 38% | 45% | 53%          |
| -25 to +25  | 52%                    | 25%         | 35% | 47% | 48% | 63% | 69% | 80%          |

|                   |     |     |     |     |     |     |     |     |
|-------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Greater than ±5%  | 86% | 96% | 93% | 88% | 85% | 81% | 82% | 80% |
| Greater than ±10% | 71% | 91% | 84% | 80% | 74% | 62% | 55% | 47% |
| Greater than ±25% | 48% | 75% | 65% | 53% | 52% | 37% | 31% | 20% |

| <b>D. Change in \$ Diversification by % Diversification Band</b> |                                  |                             |     |     |     |     |     |                            |
|--|----------------------------------|-----------------------------|-----|-----|-----|-----|-----|----------------------------|
| % Change in Div \$   | Percentage Diversification Bands |                             |     |     |     |     |     |                            |
|  | All                              | 75 Least Diversified (memo) | A   | B   | C   | D   | E   | 75 Most Diversified (memo) |
| -5 to +5   | 14%                              | 1%                          | 3%  | 7%  | 10% | 16% | 34% | 57%                        |
| -10 to +10   | 29%                              | 5%                          | 10% | 13% | 17% | 34% | 72% | 83%                        |
| -25 to +25   | 52%                              | 17%                         | 19% | 33% | 48% | 68% | 94% | 93%                        |

|                   |     |     |     |     |     |     |     |     |
|-------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Greater than ±5%  | 86% | 99% | 97% | 93% | 90% | 84% | 66% | 43% |
| Greater than ±10% | 71% | 95% | 90% | 87% | 83% | 66% | 28% | 17% |
| Greater than ±25% | 48% | 83% | 81% | 67% | 52% | 32% | 6%  | 7%  |

Appendix 2/Exhibit 5

% Difference from CoMaxLine% - Risk Approach to Correlation Matrix Approach

| A. Change in RBC UW Risk Value by RBC UW Risk Value Size Band |                        |             |      |      |      |      |      |              |
|---|------------------------|-------------|------|------|------|------|------|--------------|
| % Change in RBC UW Risk Value                                 | RBC UW Risk Size Bands |             |      |      |      |      |      |              |
|   | All                    | Tiny (memo) | A    | B    | C    | D    | E    | Jumbo (memo) |
| -5 to +5  | 76%                    | 55%         | 68%  | 72%  | 73%  | 82%  | 85%  | 91%          |
| -10 to +10  | 93%                    | 91%         | 89%  | 89%  | 94%  | 96%  | 97%  | 97%          |
| -25 to +25  | 100%                   | 100%        | 100% | 100% | 100% | 100% | 100% | 100%         |

|                   |     |     |     |     |     |     |     |    |
|-------------------|-----|-----|-----|-----|-----|-----|-----|----|
| Greater than ±5%  | 24% | 45% | 32% | 28% | 27% | 18% | 15% | 9% |
| Greater than ±10% | 7%  | 9%  | 11% | 11% | 6%  | 4%  | 3%  | 3% |
| Greater than ±25% | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  | 0%  | 0% |

| B. Change in RBC UW Risk Value by % Diversification Band |                                  |                             |      |      |      |     |      |                            |
|--|----------------------------------|-----------------------------|------|------|------|-----|------|----------------------------|
| % Change in RBC UW Risk Value                            | Percentage Diversification Bands |                             |      |      |      |     |      |                            |
|  | All                              | 75 Least Diversified (memo) | A    | B    | C    | D   | E    | 75 Most Diversified (memo) |
| -5 to +5   | 76%                              | 100%                        | 98%  | 67%  | 61%  | 69% | 84%  | 93%                        |
| -10 to +10   | 93%                              | 100%                        | 100% | 96%  | 83%  | 87% | 98%  | 100%                       |
| -25 to +25   | 100%                             | 100%                        | 100% | 100% | 100% | 99% | 100% | 100%                       |

|                   |     |    |    |     |     |     |     |    |
|-------------------|-----|----|----|-----|-----|-----|-----|----|
| Greater than ±5%  | 24% | 0% | 2% | 33% | 39% | 31% | 16% | 7% |
| Greater than ±10% | 7%  | 0% | 0% | 4%  | 17% | 13% | 2%  | 0% |
| Greater than ±25% | 0%  | 0% | 0% | 0%  | 0%  | 1%  | 0%  | 0% |

| C. Change in \$ Diversification by RBC UW Risk Value Size Band |                        |             |     |     |     |     |     |              |
|--|------------------------|-------------|-----|-----|-----|-----|-----|--------------|
| % Change in Div \$   | RBC UW Risk Size Bands |             |     |     |     |     |     |              |
|  | All                    | Tiny (memo) | A   | B   | C   | D   | E   | Jumbo (memo) |
| -5 to +5   | 21%                    | 11%         | 13% | 15% | 19% | 26% | 31% | 32%          |
| -10 to +10   | 35%                    | 13%         | 21% | 29% | 31% | 42% | 50% | 51%          |
| -25 to +25   | 58%                    | 28%         | 43% | 52% | 58% | 64% | 74% | 76%          |

|                   |     |     |     |     |     |     |     |     |
|-------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Greater than ±5%  | 79% | 89% | 87% | 85% | 81% | 74% | 69% | 68% |
| Greater than ±10% | 65% | 87% | 79% | 71% | 69% | 58% | 50% | 49% |
| Greater than ±25% | 42% | 72% | 57% | 48% | 42% | 36% | 26% | 24% |

| D. Change in \$ Diversification by % Diversification Band |                                  |                             |     |     |     |     |     |                            |
|---|----------------------------------|-----------------------------|-----|-----|-----|-----|-----|----------------------------|
| % Change in Div \$  | Percentage Diversification Bands |                             |     |     |     |     |     |                            |
|   | All                              | 75 Least Diversified (memo) | A   | B   | C   | D   | E   | 75 Most Diversified (memo) |
| -5 to +5  | 21%                              | 0%                          | 4%  | 8%  | 10% | 31% | 51% | 60%                        |
| -10 to +10  | 35%                              | 5%                          | 16% | 15% | 16% | 47% | 79% | 91%                        |
| -25 to +25  | 58%                              | 16%                         | 26% | 30% | 56% | 81% | 98% | 100%                       |

|                   |     |      |     |     |     |     |     |     |
|-------------------|-----|------|-----|-----|-----|-----|-----|-----|
| Greater than ±5%  | 79% | 100% | 96% | 92% | 90% | 69% | 49% | 40% |
| Greater than ±10% | 65% | 95%  | 84% | 85% | 84% | 53% | 21% | 9%  |
| Greater than ±25% | 42% | 84%  | 74% | 70% | 44% | 19% | 2%  | 0%  |