Peaks and Troughs:
Reserving Through the Market Cycle

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Abstract It is well-known that the carried reserve adequacy of the property & casualty industry as a whole varies across the market cycle. We examine the extent to which this variation results from actuarial methods themselves, concluding that about half of the industry's historical deficiencies and redundancies have resulted from actuarial methods. The deficiencies and redundancies that result from actuarial methods appear to be highly correlated with the economic cycle. At the same time, there is also a strong relationship between the underwriting cycle and carried reserve adequacy. Implications for uncertainty in the industry's aggregate reserve adequacy as well as for individual companies are considered.

Keywords. Reserving, reserve variability, reserving methods.

1. INTRODUCTION

It is well-known that the carried reserve adequacy of the property & casualty industry, as a whole, varies significantly across the market cycle.[1] Much less understood is the extent to which this may stem, in part, from actuarial reserving methods. If a material relation exists, any cyclicality in actuarial reserving methods could lead to over-estimated or under-estimated reserves, thus exacerbating the market cycle.

Within this paper we will assess the potentially cyclical behavior of various actuarial reserving methods. These include the paid and incurred (i.e., paid plus case) chain ladder, Berquist-Sherman, and Munich Chain Ladder methods. A complete list of methods analyzed can be found in Appendix A. For purposes of discussion, we will focus on the most commonly used of these methods, noting that the general pattern of results is consistent across all methods considered. Data has been obtained at an industry aggregate level from SNL Financial for statement years 1996 and subsequent. Data for all prior statement years was obtained from AM Best's Aggregates & Averages.
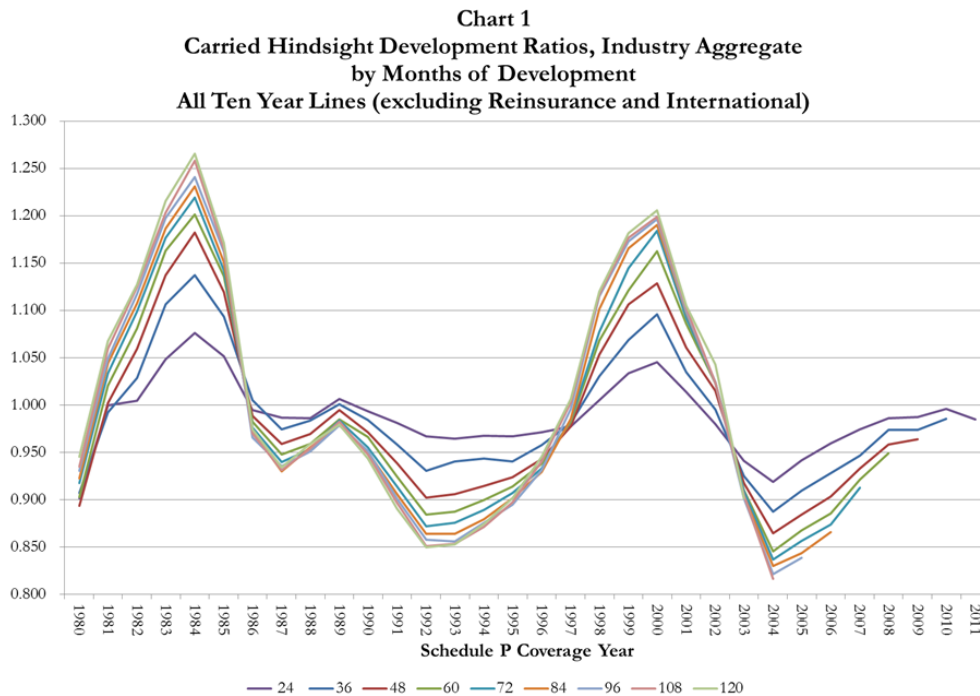
The remainder of the paper proceeds as follows. Section 2 discusses the property & casualty industry's historical carried reserve development, while Section 3 provides a summary of the actuarial research that has been performed to date in this area. Section 4 discusses the development that would have resulted from applying standard actuarial methods to data at an industry aggregate

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[1] See, for example, [5], [13], and pages 13 and 14 of [8].

level and compares these results to the carried reserve development first discussed in Section 2. Section 5 discusses the relationship of the reserving cycle to the underwriting cycle and economic cycle. Lastly, Section 6 discusses certain limitations of the analysis, while Section 7 offers some conclusions.

2. DEVELOPMENT OF THE CARRIED RESERVE

Carried reserve adequacy for the property & casualty industry has varied significantly over time. This can be seen by reviewing the development of the carried loss and DCCE[2] reserve by accident year at successive evaluations. Chart 1 shows the proportional development of the industry's carried loss and DCCE by Schedule P coverage year[3] from the initial carried reserve (at twelve months of development) to the final carried amount, as measured by ratios to the initial carried loss and DCCE reserve:

Chart 1
Carried Hindsight Development Ratios, Industry Aggregate
by Months of Development
All Ten Year Lines (excluding Reinsurance and International)

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[2] We will refer in this monograph to DCCE, although this term should be taken to refer to ALAE for those historical evaluations at which ALAE was provided as a subset of LAE within the Annual Statement, as opposed to DCCE. The change from ALAE to DCCE within the Annual Statement (beginning with the 1998 Annual Statement) would have a small effect on our analysis, although it is our perception that this change in Statutory accounting practice is immaterial to our results.

[3] i.e., report year for claims-made lines of business and accident year for all other lines of business.

Chart 1 provides ratios of the carried hindsight unpaid[4] loss and DCCE by accident year at various months of development (in the numerator) to the initial carried loss and DCCE reserve at twelve months of development (in the denominator). We will refer to these as hindsight development ratios. In particular, as these are based on the carried loss and DCCE reserves, we will refer to them as the carried hindsight development ratios.

Thus on an accident year basis we see that carried reserves developed adversely in the early 1980s (with the exception of coverage year 1980 when carried reserves developed favorably). During the following decade, reserve development was favorable. At the tail end of the 1990s until 2002, development was again adverse. Subsequently the industry has demonstrated favorable development, again measured on an accident year basis.

Analogous charts by line of business are provided in Appendix B. In general these charts show the same pattern of development as in Chart 1. However the degree of favorable or adverse developments is seen to be typically greater for the longer-tailed lines of business (e.g., medical professional liability and workers' compensation) and to be typically less for the shorter-tailed lines of business (e.g., auto liability and homeowners/farmowners).[5]

Thus the industry as a whole has clearly demonstrated a cyclical reserving pattern. At times the impact of this cycle on reserve adequacy has been quite significant. Chart 2 aggregates the industry's development on a statement year basis and compares it to the industry's carried reserves at the given evaluation:

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[4] The hindsight unpaid is the amount unpaid as of the prior evaluation (in this case, as of twelve months of development) based on estimated liabilities at a subsequent (i.e., "hindsight") evaluation. Mathematically, the hindsight unpaid loss and DCCE can be calculated as the ultimate loss and DCCE evaluated as of a subsequent evaluation less the paid loss and DCCE as of the prior evaluation. Equivalently, the hindsight unpaid loss and DCCE is the estimated unpaid loss and DCCE as of the earlier evaluation plus any change in the estimated ultimate loss and DCCE between the initial and hindsight evaluations.

[5] Lines of business have been combined within Appendix B into those lines in place during the 1980s (e.g., the occurrence and claims-made segments of medical professional liability have been combined into a single line of business, as have personal and commercial auto liability).

Chart 2
Property & Casualty Industry Total -- All Lines of Business
Carried Loss & DCCE Reserves and Subsequent Development
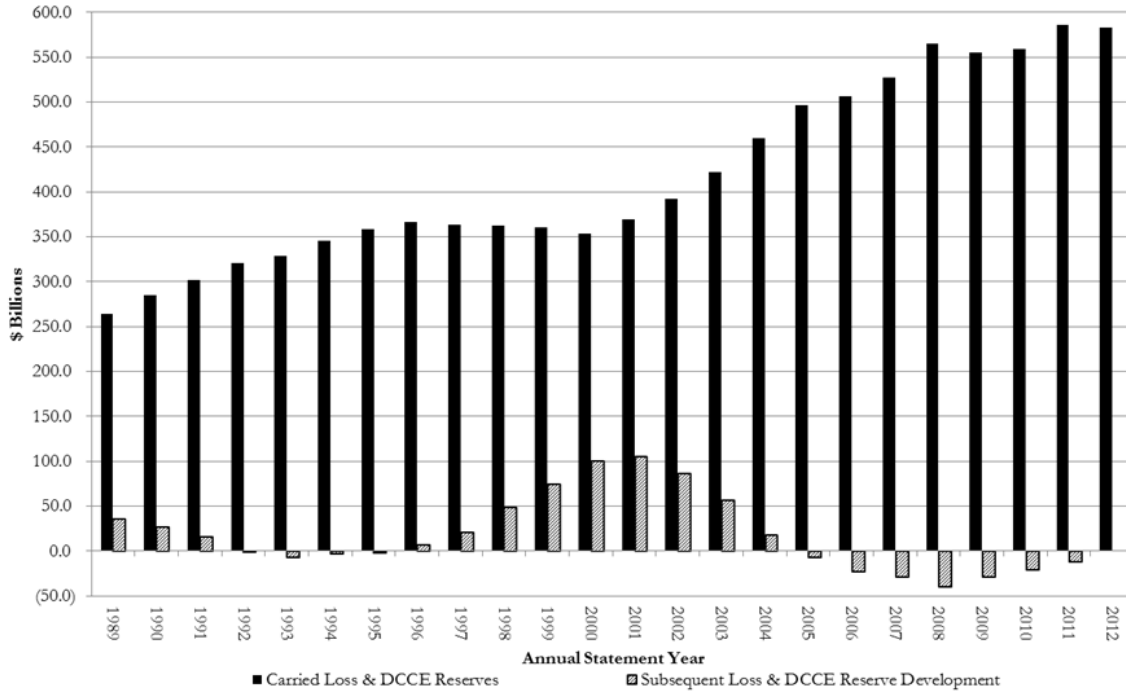
Taking statement year 2000 as an example, the above chart shows that the property & casualty industry carried $353.6 billion in net loss and DCCE reserves as of December 31, 2000. Aggregating data by calendar year shows $100.8 billion in adverse development since this accounting date. In other words, with the benefit of hindsight, the industry's net carried loss and DCCE reserves as of December 31, 2000 were deficient by at least $100 billion, or 28% of the carried reserve.[6] Thus clearly the issue of reserve adequacy is significant for the property & casualty industry.

3. SUMMARY OF PRIOR RESEARCH

Surprisingly, very little research has been done to date on the source of cyclicality in carried reserve estimates, and in particular on the relationship between actuarial methods and carried reserves. We are aware of one published paper to date on this topic by a US actuary. In this paper, the author compares the booked ultimate loss and DCCE ratios for Commercial Auto Liability on an industry aggregate basis to the loss and DCCE ratios that would have been indicated by applying

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[6] Given the ten-year structure of the Schedule P triangles, this estimate excludes all development subsequent to December 31, 2009, which has been consistently adverse for "prior" accident years. Offsetting this additional unknown amount, some amount of adverse development would be due to the unwinding of the discount in cases where discounting was permitted.

standard actuarial methods to the data available within Schedule P. The author's approach is similar to our own, although applied only to one line of business and only to accident years 1995 through 2001.

The author observes that, although the pattern exhibited by the carried ultimate loss and DCCE ratios by accident year has been directionally similar to the results of the actuarial indications, the carried loss and DCCE ratios have been consistently lower than the actuarial indications and have also exhibited greater error when evaluated in hindsight (i.e., when compared to the final carried amounts). He concludes that "either the booked ultimate loss ratios were based on other methods that are inferior to the chain ladder and Bornhuetter-Ferguson or judgmental adjustments were made to the indicated ultimate loss ratios that reduced the quality of the final selections."[7] The author acknowledges that "further research would be required to determine whether this is a general loss reserving phenomenon or one confined to Commercial Auto Liability during the time period studied." [8]

More research has been done on this topic by UK actuaries, as documented in [13]. In particular, a GIRO[9] working party concluded the following in 2003: [10]

a) A reserving cycle exists in the UK.

b) Standard actuarial reserving methods are probably a contributory cause of the reserving cycle.

c) There is some (inconclusive) evidence that development patterns vary with the underwriting cycle, tending to be longer-tailed when premium rates are low.

d) There is clear evidence that Lloyd's premium rate indices had tended to understate the true magnitude of the underwriting cycle.

However the GIRO working party does not appear to have considered the relationship between the reserving cycle and the economic cycle. In this paper, we will assess the extent to which the above observations hold for the US property and casualty industry, as well as the relationship between the reserving cycle and the economic cycle. To the best of our knowledge, the relationship between the economic cycle and actuarial reserving methods has not been considered previously.

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[7] Page 1 of [8].
[8] Ibid.
[9] General Insurance Research Organizing Committee of the Institute and Faculty of Actuaries.
[10] As cited on page 401 of [13], from which these conclusions are paraphrased.

4. DEVELOPMENT OF THE ACTUARIALLY INDICATED UNPAID AMOUNT

A similar analysis to that shown in Section 2 above can be performed based on the results of standard actuarial methods applied to the data given within Schedule P. As an example, consider the results of the paid development method applied based on all-years weighted average development factors to each ten-year line of business within Schedule P, aggregated here:
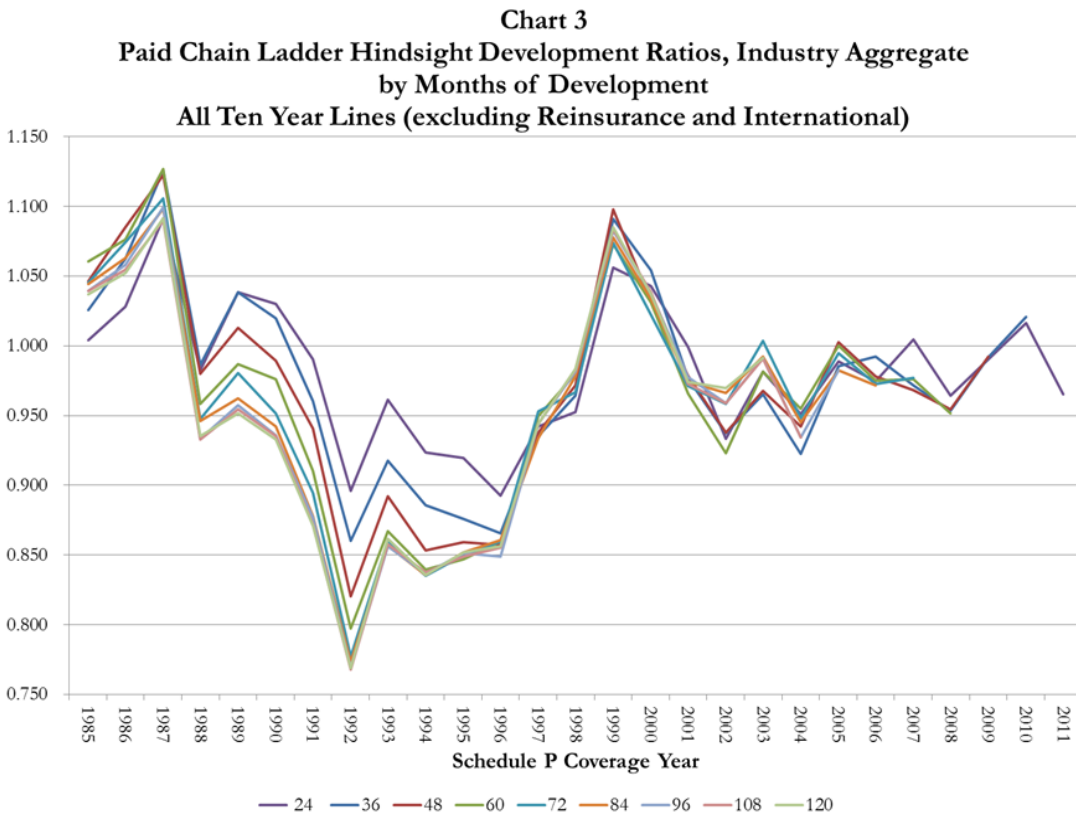

Chart 3 shows that the paid development method would have resulted in adverse development in the mid-1980s and favorable development between 1988 and 1998. Development would have been adverse for accident years 1999 and 2000 and generally favorable subsequently. It is interesting both that the paid development method evidences cyclicality in its results and also that this cycle follows the same general pattern of the carried reserves. Chart 4 compares development for the carried reserves to development of the industry aggregate paid and incurred (i.e., paid plus case) chain ladder methods, focusing on development from 12 months of development to the most recent available evaluation:

Chart 4
Hindsight Development Ratios, Industry Aggregate
All Ten Year Lines (excluding Reinsurance and International)

Thus the industry's pattern of carried reserve development generally shows a similar pattern, although at times more pronounced, as that exhibited by the paid and incurred chain ladder methods. It should be noted that based on a review of industry aggregate case reserve averages by line of business, case reserve adequacy appears to have declined at 12 months of development for accident years 1999 and 2000. This likely explains (at least in part) the greater degree of adverse development exhibited by the incurred chain ladder method for these accident years.

It is reasonable to ask whether the deficiencies or redundancies that would have resulted from the use of the paid and incurred chain ladder methods at these times could have been obviated or even eliminated. Perhaps this could result from the use of more recent (i.e., shorter-term) development factors or by adjustments stemming from diagnostic information available at the time, such as claim closure rates or paid-to-incurred ratios. There is some evidence for the predictive value of these diagnostics. As an example, consider Chart 5, which compares the ratios of paid-to-incurred loss and DCCE as of twelve months of development on the *x*-axis with the ratios of paid loss and DCCE as of twelve months of development to the ultimate loss and DCCE as of the most recent evaluation (i.e., the hindsight percentage of loss and DCCE paid, on the *y*-axis):

Chart 5
Paid-to-Incurred vs. Hindsight Percentage Paid
Industry Aggregate
**All Ten Year Lines (exluding Reinsurance and International)**
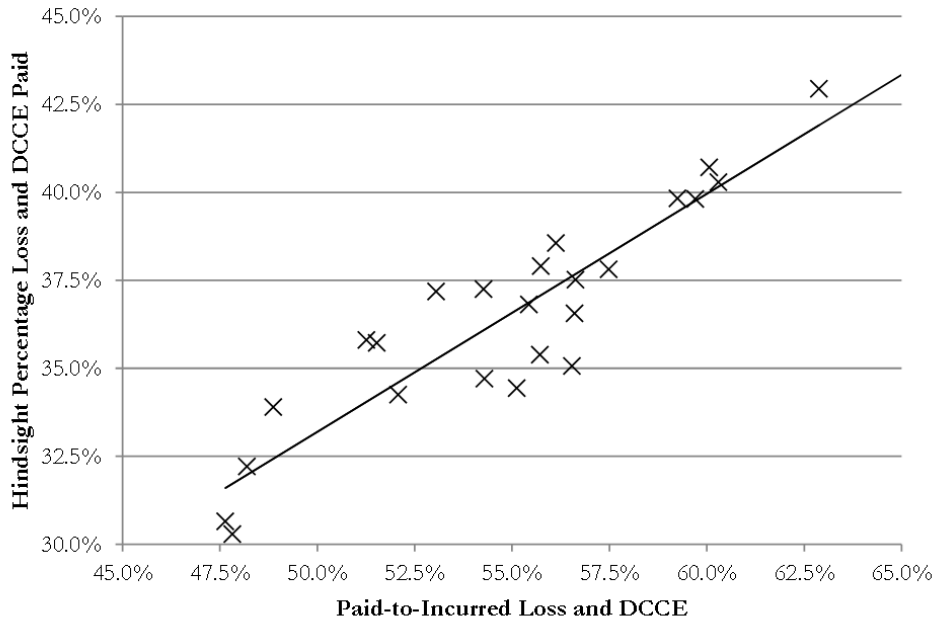
Note that the inverse of the hindsight percentage paid would be the hindsight cumulative paid development factor. Thus the paid-to-incurred ratio is clearly indicative of a paid development factor on an industry aggregate basis (note that the R-squared for the above linear fit is 83%). At the same time, the deviation of these points from the fitted line is demonstrative of the uncertainty that will always be present in any estimation of the future payments. While Chart 5 reflects data for all lines combined, analogous data by line of business, shown in Appendix C, demonstrates similar results. [11]

The results shown on Chart 5 strongly suggest the use of methods that would adjust for changes in payment patterns or case reserve adequacy over time. These methods would include the Berquist-Sherman and Munich Chain Ladder methods, as well as versions of the paid and incurred chain ladder methods in which more recent development factors are relied upon as the prospective selections. Chart 6, below, compares the results of these methods:

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[11] The R-squared values by line of business range from 54% to 91%, with the exception of workers' compensation, for which the R-squared is 1%. This may stem from the statutory nature of workers' compensation payments, which might make fluctuations in case reserves more suggestive of changes in case reserve adequacy than changes in future payments. However, this statement may be false if triangles longer than ten years are examined, as increases in case reserves could suggest longer life expectancy, for example, which would typically not result in increased payments during a time period short enough to be reflected in a ten-year triangle.

Chart 6
Hindsight Development Ratios, Industry Aggregate
All Ten Year Lines (excluding Reinsurance and International)
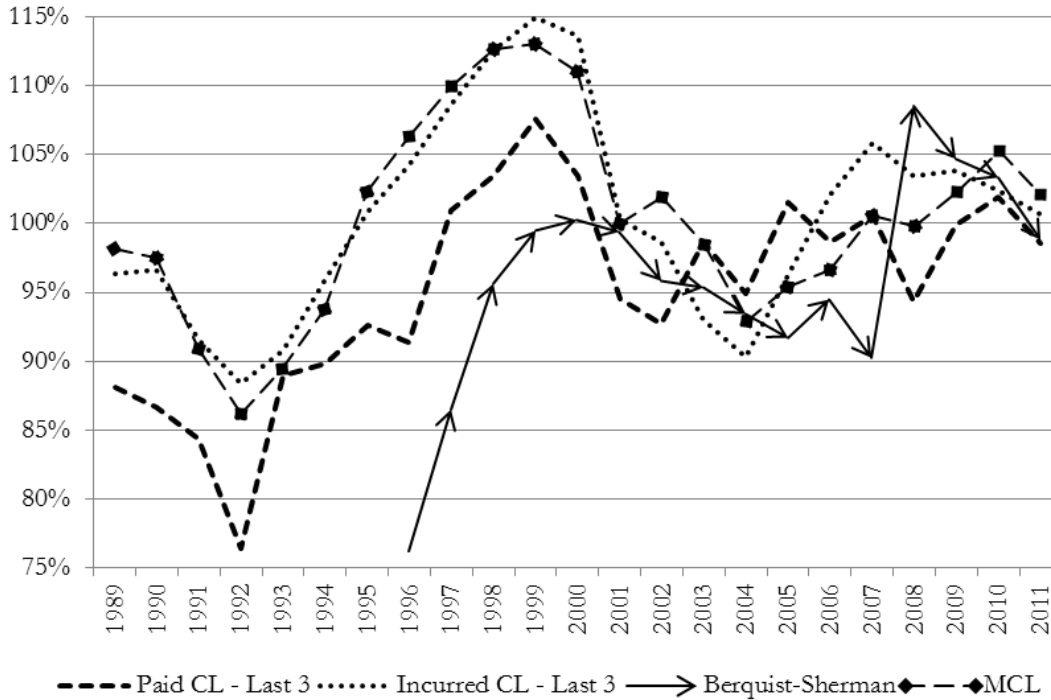
In general the Munich Chain Ladder method shows similar results to the Incurred Chain Ladder method. The Berquist-Sherman method appears to outperform the Incurred Chain Ladder method at this aggregate level at only some evaluations, and in particular the method underperformed during the first years for which claim counts were required in the Annual Statement (beginning in 1996). Presumably this is due to irregularities in the claim count data at that time. In addition, at the 2007 evaluation there appears to be an overstatement (relative to surrounding evaluations) in the number of open personal auto liability claims, which causes the Berquist-Sherman method to overstate unpaid loss and DCCE at this evaluation.

Consider the paid chain ladder method in which a weighted average of the last three development factors is assumed as the prospective selection (also included on Chart 6). For purposes of this analysis, we observe that this method appears to outperform the other methods considered, beginning in the late 1990s. For this reason, we have treated the results of this method at the most recent evaluation available as the "true" ultimate loss and DCCE, where such an ultimate was needed (i.e., the 2004 accident year and subsequent, where the incurred loss and DCCE as of 120

months of development would not yet be available). This method was used as such above in Chart 5, for example.

All methods listed in Appendix A were reviewed in an analogous fashion to the methods discussed here. In general the other methods performed similarly or in some cases underperformed the methods we have discussed in this section. Thus any solution to the cyclical behavior of actuarial reserving methods appears to be non-trivial. Appendix D provides information analogous to Chart 6 by line of business. In general results are consistent across lines of business.

As a note, the cyclical behavior we have observed also holds for methods such as the frequency/severity and loss ratio methods. Given that the loss ratios of the property & casualty industry themselves exhibit cyclicality (as a result of the underwriting cycle) it is not surprising that the loss ratio method would exhibit cyclicality in its hindsight development ratios as well. It is more interesting that the cyclicality holds even after contemporaneous attempts to adjust for the underwriting cycle. Chart 7 shows the hindsight development ratios of these methods aggregated across all ten-year lines of business:

Chart 7
Hindsight Development Ratios, Industry Aggregate
All Ten Year Lines (excluding Reinsurance and International)
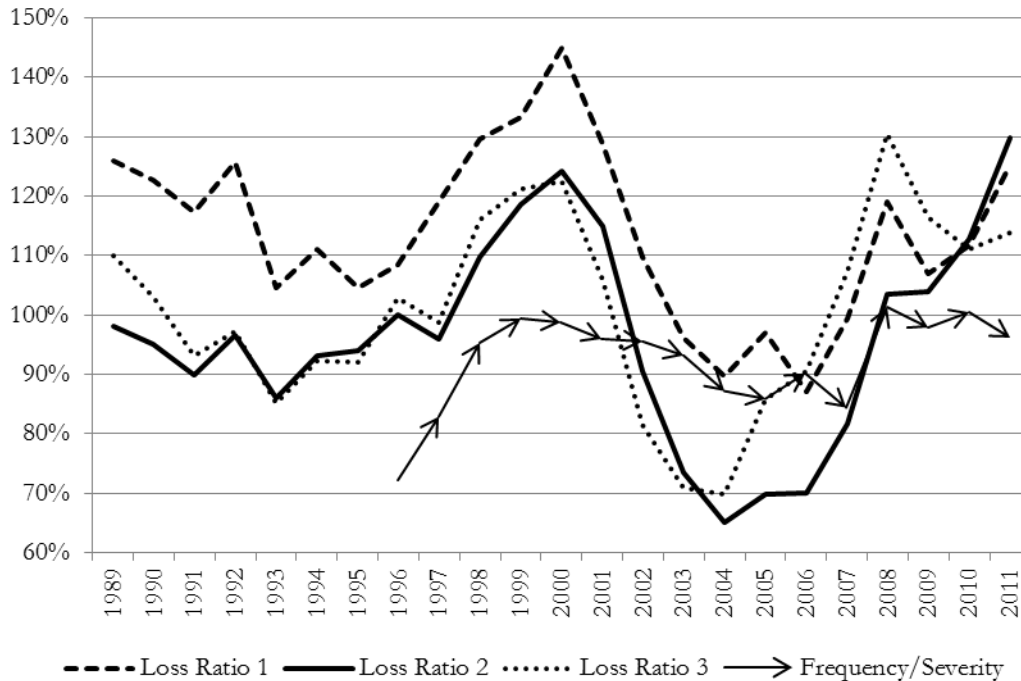
Recall that definitions of the above methods are available in Appendix A. Clearly, deviation of the hindsight development ratios of the loss ratio methods from unity must result from variation in the property and casualty industry's loss and DCCE ratios over time. For example, business in the 1999 through 2001 coverage years was underpriced relative to prior coverage years, so we would naturally expect indications based on these prior coverage years to be deficient (as the lines above for Loss Ratio 2 and Loss Ratio 3 show them to be).

The contemporaneous loss and DCCE ratio estimates are given by the method Loss Ratio 1. These estimates underperform in earlier years but have improved in their performance since 2003. Note this is consistent with the conclusions of the 2003 GIRO working party report, mentioned previously, which noted that the Lloyd's premium rate indices tended to understate the magnitude of the underwriting cycle. Thus contemporaneous estimates of both the US and UK industries have historically underestimated the effect of the underwriting cycle.

By way of summarizing the above discussion, we provide the following table of correlations and *R*-squared values between the hindsight development ratios of the carried loss and DCCE and those of the actuarial indications:
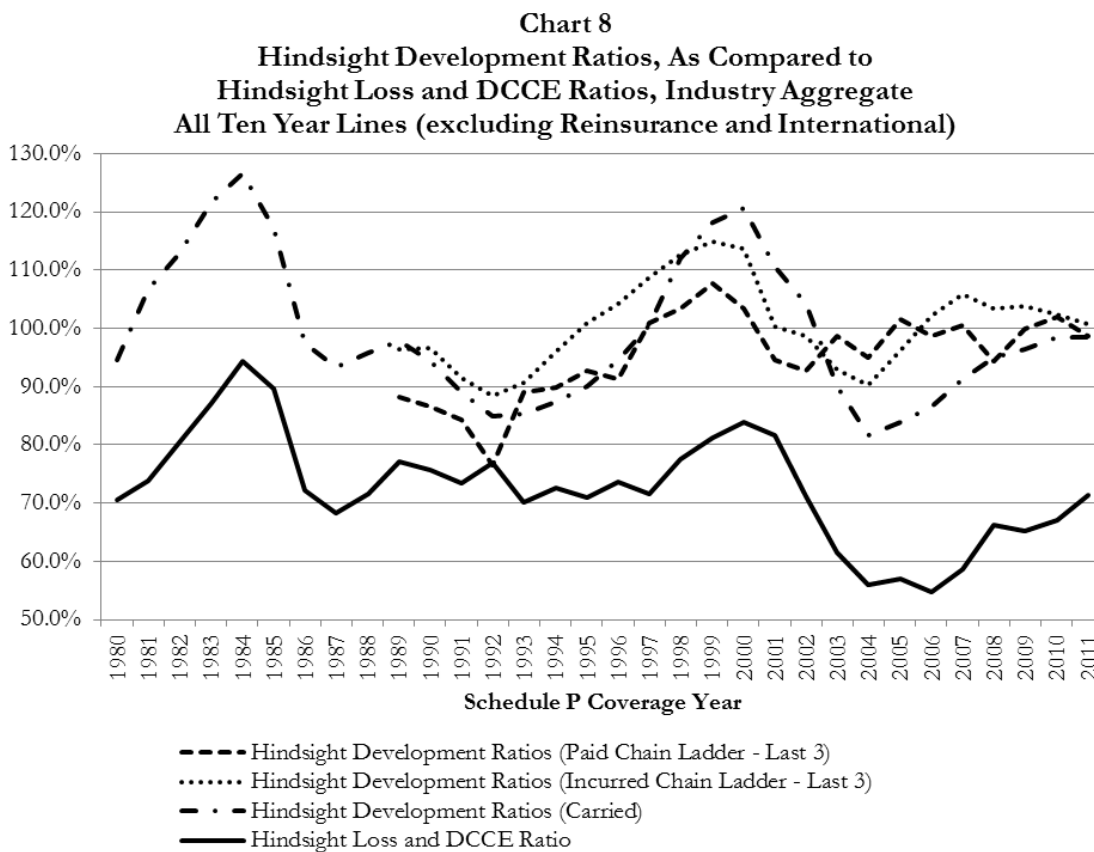
Table 1 Correlations and R-Squared Values of Hindsight Development Ratios of Carried Unpaid Loss and DCCE and Actuarially Indicated Unpaid Loss and DCCE		
Actuarial Method	Correlation	R-Squared
Paid Chain Ladder – All Years Weighted Average Development Factors	63%	40%
Paid Chain Ladder – Three Years Weighted Average Development Factors	52%	27%
Incurred Chain Ladder – All Years Weighted Average Development Factors	94%	89%
Incurred Chain Ladder – Three Years Weighted Average Development Factors	78%	61%
Berquist-Sherman	27%	7%
Munich Chain Ladder	81%	66%

For example, the 63% correlation in the first row of the above table represents the correlation between the "carried" and "paid chain ladder" lines on Chart 4 for accident years 1989 and subsequent. The 40% R-squared value represents the R-squared between these lines, where the "carried" is treated as the dependent variable and the "paid chain ladder" as the independent variable. In other words, given the variation in carried reserve adequacy at first evaluations by accident year, 40% is estimated to be due to underlying variation that is also present in the paid chain ladder method. Appendix E provides results analogous to the above table by line of business.

Given the range in the above table, we can conclude that perhaps about half of the historical variability in carried reserve adequacy can be attributed to an underlying cyclicality that is present in actuarial methods. It would greatly benefit the actuarial profession to investigate possible new methods that mitigate this cyclicality. While mitigating the cyclicality may be possible, it seems unlikely that the cyclicality can be eliminated. Some amount – likely a large amount – of uncertainty in industry reserve adequacy will always be present due to the uncertainty in future payments. Even if the cyclicality can be addressed and managed, significant uncertainty in results – even at an industry aggregate level – will continue to exist.

5. RELATIONSHIP TO THE UNDERWRITING AND ECONOMIC CYCLES

It is natural to ask whether there is a relationship between the reserving cycle and other known cycles, such as the underwriting cycle and the economic cycle. Considering first the underwriting cycle, Chart 8 demonstrates a possible relationship between reserve development and the pricing of property and casualty business:

Chart 8
Hindsight Development Ratios, As Compared to
Hindsight Loss and DCCE Ratios, Industry Aggregate
All Ten Year Lines (excluding Reinsurance and International)

- - - - Hindsight Development Ratios (Paid Chain Ladder - Last 3)
.... Hindsight Development Ratios (Incurred Chain Ladder - Last 3)
- · - Hindsight Development Ratios (Carried)
——— Hindsight Loss and DCCE Ratio

Here the underwriting cycle is represented by the hindsight (i.e., actual) loss and DCCE ratio by coverage year. Reserve development is represented by the hindsight development ratios. Chart 8 suggests a strong relationship between carried reserve adequacy and the underwriting cycle. It is interesting that, at the same time, there is essentially no correlation between the hindsight development ratios of the paid chain ladder method and the underwriting cycle. Table 2 provides the correlations between the above hindsight development ratios and the hindsight loss and DCCE ratios:
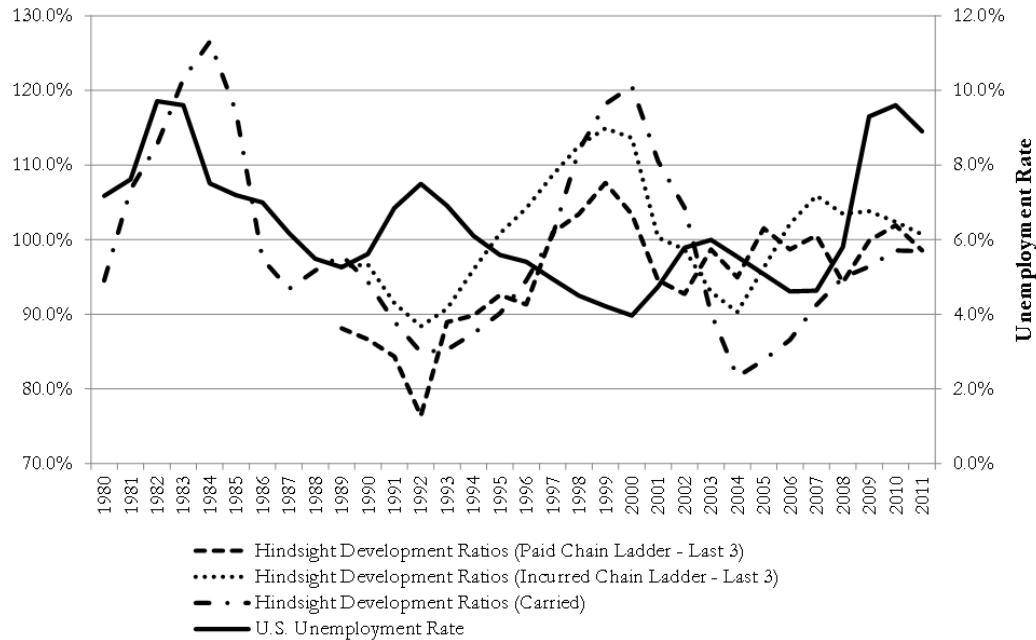
Table 2 Correlations of Hindsight Development Ratios with The Hindsight Loss and DCCE Ratios		
Indication	Correlation	Shifted Correlation[12]
Paid Chain Ladder – Three Years Weighted Average Development Factors	-18%	2%
Incurred Chain Ladder – Three Years Weighted Average Development Factors	31%	51%
Carried Reserves	82%	73%

Chart 9 is similar to Chart 8, but compares the hindsight development ratios to the economic cycle, as represented by the unemployment rate:

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[12] Shifted correlation in this context refers to the correlation of the hindsight loss and DCCE ratios with the prior coverage year's hindsight development ratio. These indications suggest there may be a lagged relationship between the reserving cycle and the underwriting cycle. This may be due to an underlying relationship between these two cycles and the economic cycle (to be discussed further below). It is possible that the underwriting cycle is essentially a lagged result of the economic cycle, as has been discussed elsewhere by other authors.

Chart 9
Hindsight Development Ratios, Industry Aggregate
As Compared to U.S. Unemployment Rate
All Ten Year Lines (excluding Reinsurance and International)

Legend:
- - - - Hindsight Development Ratios (Paid Chain Ladder - Last 3)
.... Hindsight Development Ratios (Incurred Chain Ladder - Last 3)
- · - · Hindsight Development Ratios (Carried)
——— U.S. Unemployment Rate

The correlations between the hindsight development ratios and the unemployment rate are given in Table 3:

Table 3 Correlations of Hindsight Development Ratios with The Unemployment Rate[13]		
Indication	Correlation Measured 1989 – 2003[14]	Correlation Measured 1989 – 2008
Paid Chain Ladder – Three Years Weighted Average Development Factors	-85%	-85%
Incurred Chain Ladder – Three Years Weighted Average Development Factors	-91%	-83%
Carried Reserves	-90%	-65%

Thus Table 3 suggests a very strong relationship between the hindsight development of actuarial methods and the underlying economic cycle. More specifically, when the unemployment rate is low, subsequent reserve development for the corresponding coverage year is adverse. Conversely,

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[13] Annual unemployment rate data was obtained from the Bureau of Labor Statistics at www.bls.gov.
[14] We have considered the correlations measured using data through 2003 and also through 2008. Both sets of indications are important. Data through 2003 (which we evaluated using hindsight data as of December 31, 2012) would be at an "ultimate" evaluation. Subsequent coverage years are not fully developed and consequently may fail to demonstrate a relationship between the reserve development that has been exhibited to date and the economic cycle. However a large portion of reserve development for coverage years through 2008 has been exhibited by December 31, 2012, and consequently these additional coverage years are useful to the analysis.

reserve development is favorable for coverage years with high unemployment.

One possible reason for this observation is the relationship between inflation and the economic cycle. Inflation would have a calendar year impact on payments and would presumably impact payment patterns over time. The economic cycle also likely influences underlying factors such as the propensity to report smaller claims. Even the underlying composition of claims would likely change, perhaps significantly, due to economic factors. Nonetheless, reasons for the impact of the economic cycle on the development of actuarial methods are far from understood.

For carried reserves the results are less conclusive. As noted in the headings of Table 3, we have focused on the years beginning in 1989 to measure the relevant correlations. That is because the actuarial indications are available at twelve months of development beginning with this year. The carried hindsight development ratios are available back to 1980. These show an essentially inverted relationship between the reserving cycle and the economic cycle, relative to subsequent years. This may be due in part to the high inflation of the early 1980s, which has not been observed subsequently. Perhaps more impactful would be asbestos and environmental losses stemming from these coverage years, recognized in the late 1980s or early 1990s.

Even when the years prior to 1989 are not considered, the correlations suggest a stronger relationship between the development of actuarial indications and the economic cycle than between carried reserve development and the economic cycle. There are likely factors influencing carried reserves that are not apparent in the actuarial indications. For example, carried reserves are influenced by the loss and DCCE ratios of recent coverage years.

When the loss and DCCE ratios are changing, the degree of change can be very difficult to estimate, and there may be a certain "anchoring" effect in the setting of carried reserves, whereby in setting reserves for a given coverage year a psychological difficulty is encountered in deviating from the results of prior coverage years. This might explain the strong relationship between the development of carried reserves and the underwriting cycle. Since the underwriting cycle appears to lag the economic cycle, this in turn may explain why the relationship between carried reserve development and the economic cycle is not as strong.

6. LIMITATIONS OF THE ANALYSIS

There are several limitations on any conclusions of the current analysis. In particular, we must recognize that the analysis has been performed on an industry aggregate basis. Hence, although patterns such as payment rates are more stable than when considered on an individual company basis, we are inherently limited in our ability to understand changes in these patterns when they occur.

Perhaps most importantly, we should not conclude that methods that appear to perform well on an industry aggregate basis would necessarily be the best methods to use in a company setting. For example, due to a limited amount of data for many companies, methods such as the frequency/severity and loss ratio methods can be integral to an actuarial analysis at early evaluations. On an industry aggregate basis, where a sufficient amount of loss data is available, we have observed that the frequency/severity and loss ratio methods underperform other methods considered (this would also be due in part to a lack of information on rate changes and, at times, inconsistency in claim counts within the Annual Statement from one evaluation to the next).

As another example, consider that case reserve adequacy appears to have changed significantly over time on an aggregate basis. As a result, the paid chain ladder method outperforms the incurred chain ladder method in the more recent years. However, changes in case reserve adequacy are not present for all companies. For any company for which case reserve adequacy has been stable, methods that reflect case reserves can be expected to outperform methods that are based on paid amounts alone.[15]

Lastly, we have assumed throughout the discussion that the results of actuarial methods applied to data at an industry aggregate level would be substantively similar to the aggregation of the results of actuarial methods applied to individual companies or books of business. It is possible that the results of our analysis would differ materially if performed on an individual company basis. However, is seems highly likely that the cyclicality we have observed is a phenomenon affecting all companies. This cyclicality would be difficult to observe for the vast majority of companies based on their individual data alone and may also be masked by the volatility of year-over-year results at this level. While the magnitude of our observations might differ if the analysis had been performed in a different manner, we believe the substance of the conclusions would remain the same.

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[15] This is particularly true for smaller companies. See [6].

7. CONCLUSIONS

The most important conclusion of the analysis is the demonstration that actuarial methods bear some attribution for deficiencies and redundancies that have been present within the carried reserves of the property and casualty industry over time. This should not be taken to assign fault to individual actuaries or to actuaries as a whole. Given the state of actuarial science at the time, actuaries were using standard and accepted – in fact, the most accepted – actuarial methods.

However, many actuaries have previously characterized the material portion of the industry's deficiency or redundancy as being the result of management decisions or unpredictable volatility (see the discussion on prior research in Section 3). Certainly there have been cases where this observation holds. However the current analysis suggests that actuarial methods may have been as great a contributor historically to the deficiency or redundancy in carried reserve levels.

Examining the results of the analysis strongly suggests that we consider whether we may be able to improve upon our most accepted methods. However, it is unclear whether such improvements are only possible for the largest insurance companies, which generally exhibit less volatility in results (not to be confused with cyclicality), or whether such methods might be helpful for smaller companies as well. A level of prediction is possible on an industry aggregate basis that is likely not present for the smaller companies within the industry.

It is also significant that even with the use of our best methods, some degree of uncertainty will exist for the industry's reserve levels, even on an aggregate basis. Historical results show that the industry's reserves may develop – favorably or adversely – by 5% to 10% of initial indicated amounts. Such development may be unpredictable based on the current state of actuarial science. Given the inevitable uncertainty in any indication of future payments, significant improvement in indications of unpaid loss and DCCE may not be possible.

These conclusions should be considered magnified for individual insurance companies. For almost all insurance companies, development in excess of the industry aggregate benchmark of 5% to 10%, mentioned above, should be considered reasonably possible. We might characterize such benchmark development as the result of "systemic risk." For small to medium-sized insurance companies in particular, development well in excess of this benchmark is a significant possibility.

Appendix A – Loss Reserving Methods

The following provides a list of the methods considered in the analysis, including the abbreviation used to refer to each method (note that for methods for which there are paid and incurred versions, multiple abbreviations are given). Also included is any relevant information as to how the method is applied within the current analysis, given the data limitations of Schedule P. As a result of these data limitations, the methods outlined below develop indications of loss at a 10th report (i.e., the last evaluation included within the Schedule P triangles) rather than indications of loss at ultimate.

1. **Backward Recursive Case Development (BRC)**

   This method is discussed by Marker and Mohl in [10]. The paid-on-prior-case and case-on-prior-case factors selected for our analysis are each the weighted average of the columns of these factors as given by the triangles, where the weights are proportional to the prior case. At a 10th report, we have assumed a paid-on-prior-case factor of 1.00 and a case-on-prior-case factor of 0.00.

2. **Benktander (BT)**

   The Benktander method, discussed in [9], is often referred to as the "iterated Bornhuetter-Ferguson method." In the BT method, a priori loss is equal to the indication from the BF method (in our case, BF1-I for the incurred method, and BF1-P for the paid method). The calculation of indicated loss then proceeds as described for the BF method, with calculations of the percent unpaid for the BT-P method and the percent IBNR for the BT-I method.

3. **Berquist-Sherman Case Adjustment (BS)**

   The BS method is the first of the two methods given in [2], in which an adjustment is made to the incurred loss in the prior diagonals of a given triangle for assumed changes in case reserve adequacy. This adjustment is made by de-trending the average case reserve along the most recent diagonal of the triangle (at rates that vary by line of business and evaluation date). The result is multiplied by the number of open claims within prior diagonals in order to obtain an indication of case reserves from prior diagonals at the approximate level of case reserve adequacy as the most recent diagonal. Incurred loss development factors are then developed and applied to loss along the most recent diagonal as for the LDF-I method.

4. **Bornhuetter-Ferguson 1 (BF1)**

   The first of the BF methods included in the analysis uses the indicated loss from the first loss ratio method (LR1), described below, as the a priori indicated loss. The percent unpaid and percent IBNR are then calculated as described in [3], producing both paid (BF1-P) and incurred (BF1-I) versions of this method.

5. **Bornhuetter-Ferguson 2 (BF2)**

   The second of the BF methods is an iterative procedure in which the a priori indicated loss is based on the weighted average loss ratios of preceding accident years, as based on the BF2 method indications for these years. The oldest accident year in the triangle, as well as any other accident year for which loss ratios of older accident years are not available, relies on the same a

priori loss ratio as the BF1 method. Both paid (BF2-P) and incurred (BF2-I) versions of this method are calculated.

6. **Brosius Least Squares (BLS)**

The BLS method considers that there may be both additive and multiplicative aspects of loss development. Thus the method iteratively develops both a multiplicative loss development factor, to be applied to losses paid or incurred to date, and an additive factor, to be included subsequent to the multiplication. The factors are based on a least squares regression, where the incurred loss ratio at a 10th report is the dependent variable and the paid or incurred loss ratio at the given evaluation is the independent variable. The use of loss ratios rather than loss is a difference from the methodology as presented in [4], and was done so as to normalize for changes in exposure across accident years. Both paid (BLS-P) and incurred (BLS-I) versions are included.

7. **Brosius Least Squares – Weighted (BLSW)**

Having observed certain indications produced by the BLS method, we sought to enhance the reliability of this method by giving more credibility in the regression process to years with greater premium, and presumably greater exposure. The Weighted Brosius Least Squares method that resulted uses a regression process weighted by premium, in contrast to the unweighted regression used in the BLS method itself.

8. **Cape Cod (CC)**

The Cape Cod method is very similar to the BF method, but develops a priori loss under the assumption that in total across accident years it should be equal to the CC method indication. For the CC method as included in this analysis, we have assumed the same loss ratio for each accident year (i.e., unlike certain of the loss ratio methods discussed below, there is no a priori difference assumed by year). Both paid (CC-P) and incurred (CC-I) versions of the method are included.

9. **Case Development Factor (CDF)**

    The CDF method is based on the loss development factors from the LDF method, discussed below. In the CDF method an indicated unpaid-to-case ratio is derived from the relationship between unpaid loss and case loss implicit in the selected paid and incurred loss development factors. This factor is then applied to the case reserve to derive an indication of unpaid loss, which is added to paid loss to date for an indication of loss incurred through the 10th report.

10. **Frequency/Severity (FS)**

    The FS method is based on a projection of reported claims at a 10th report and a severity applied to these claims. Reported claims are based on the company's triangular reported claims data (i.e., Section 3 of Part 5 of Schedule P for the given line of business) developed to a 10th report using weighted average reported claim development factors. Given the relatively favorable performance of the LDF-I method as well as its general acceptance within actuarial practice, we took the LDF-I method to be the "preliminary" selected method for use in selecting severities.

    Thus the severity for each accident year is calculated as the incurred loss at a 10th report indicated by the LDF-I method divided by the indicated reported claims at a 10th report. For a given accident year, a severity is selected based on the weighted average severities of all prior accident years, where the weights are proportional to the projected reported claims. In this process, the severities are trended to the accident year in question at rates that vary by line of business and evaluation date.

11. **Hindsight Outstanding/IBNR (HS)**

    The HS method is similar to the FS method in that it relies on an equivalent projection of reported claims as well as a preliminary selected loss method (also the LDF-I method). However within the HS method, the projection of reported claims is used to calculate a triangle of "hindsight outstanding" claims, which are the difference between the projection of reported claims at a 10th report and closed claims to date. Similarly, the preliminary selected loss method is used to calculate a triangle of hindsight outstanding loss, which is the difference between the preliminary method loss projections and the paid or incurred loss to date. Thus the difference represents unpaid loss for the HS-P method and IBNR loss for the HS-I method.

    The ratios of the values within the hindsight outstanding loss triangle to the corresponding values within the hindsight outstanding claims triangle produces a triangle of hindsight outstanding severities (unpaid severities for the HS-P method and IBNR severities for the HS-I method). For a given accident year, severities from the preceding years are trended at set rates that vary by line of business and evaluation date. A weighted average of these severities, where the weights are proportional to hindsight outstanding claims, is selected.

    The weighted average hindsight severity is then applied to the number of projected outstanding claims for the given accident year to produce indications of unpaid loss for the HS-P method and IBNR loss for the HS-I method. These are then added to paid loss or incurred loss, respectively, to derive indications of incurred loss at a 10th report. This method is also referred to as the "ultimate unclosed claim severity technique" within [7].

12. Incremental Additive (IA)

In this method, incremental (i.e., calendar year) changes in paid or incurred loss are observed by accident year and compared to the premium for that year. A weighted average ratio of incremental loss to premium is selected, where the weights are proportional to the premium. These ratios are accumulated to derive an IBNR-to-premium or unpaid-to-premium ratio at the given evaluation. The ratios are applied to premium to derive IBNR or unpaid loss itself, then added to incurred loss or paid loss, respectively, for the IA-I and IA-P methods. So that the IA-P method will produce an indication of incurred loss at a 10th report, the unpaid-to-premium ratio at a 10th report is set equal to the case-to-premium ratio at a 10th report of the earliest year in the triangle.

13. Incremental Claims Closure (ICC)

The incremental claims closure method is described by Adler and Kline in [1]. In this method, reported claims at a 10th report are projected based on the reported claims triangle and weighted average reported claims development factors selected from this triangle (as above for the FS and HS methods). A closing pattern is then selected based on historical weighted average incremental closed-on-prior-open factors, where the weights are proportional to the number of claims open. These factors are then applied iteratively to project incremental closed claims, with the difference between the projected reported claims at the 10th report and the projected closed claims at the 10th report being the number of claims projected to close after the 10th report.

As the next step, historical incremental paid loss is compared to incremental closed claims to derive incremental paid loss per closed claim by time period. These amounts are then trended at rates that vary by line of business and evaluation date to the relevant time period and a weighted average of the indications selected (where the weights are proportional to the number of closed claims). Prospective incremental paid loss by accident year is then projected as the product of the projected incremental closed claims and the projected paid loss per closed claim, each for the same time period. Ultimate loss is then the sum of these projections with paid loss to date. Within the current analysis, claims that are projected to close after the 10th report are assumed to have a severity equal to that of the claims that close between the 9th and 10th reports, but trended one additional year.

14. Incremental Multiplicative (IM)

The incremental multiplicative method is similar to the incremental additive method in that both methods consider incremental loss triangles. However, the IM method calculates development factors that are ratios of incremental loss in one time period to the incremental loss in the preceding time period. Weighted averages of these development factors are calculated, where the weights are proportional to the incremental loss in the preceding time period.

The development factors are then applied iteratively to project incremental loss in subsequent time periods. Projections of unpaid loss and IBNR loss are derived for the IM-P and IM-I methods, respectively, by accumulating the indications of incremental paid and incremental incurred loss by time period. These projections of unpaid loss and IBNR loss are added to paid loss to date and incurred loss to date, respectively, to derive distinct indications of ultimate loss.

Within the IM-P method, a tail factor from paid loss at a 10th report to a level reflecting incurred loss at a 10th report is selected based on the oldest accident year in the triangle and the assumption that the case loss within this accident year will be paid as is. In other words, the tail factor is the case loss for this year divided by the incremental paid loss for this year in the time period preceding the 10th report. If incremental paid loss for this time period is zero, then such a ratio is undefined and assumed to be zero for purposes of our analysis.

15. **Loss Development Factor (LDF)**

The LDF methods are based on the calculation of historical loss development factors from the paid and incurred triangles. The weighted average loss development factor from all available years within the triangle is applied to loss at the given evaluation date to derive indicated loss at a 10th report. Both paid (LDF-P) and incurred (LDF-I) versions of this method are included within the analysis. For the paid method, a tail factor to develop the losses from paid at a 10th report to incurred at a 10th report is equal to the incurred-to-paid ratio at a 10th report for the earliest year in the triangle.

16. **Loss Ratio – Based on A Priori Assumption (LR1)**

Three versions of the loss ratio method are included within our analysis. Each relies on net earned premium by calendar year, consistent with the use of net paid and incurred loss within the triangles. The first of these (LR1) is based on a priori industry indications of the loss ratio for the given coverage year. These loss ratios were derived from historical A.M. Best Review & Preview reports.

17. **Loss Ratio – Based on Preliminary Selected for Prior Years (LR2)**

The remaining two loss ratio methods are each based on the use of preliminary selected incurred loss at a 10th report, which for both is set equal to the results of the LDF-I method, consistent with the preliminary selected loss in the FS and HS methods. For the LR2 method, the loss ratio for a given accident year is set equal to the weighted average of the loss ratios produced by the preliminary selected method within the preceding accident years of the triangle, where the weights are proportional to net earned premium. This loss ratio is then multiplied by net earned premium for the given calendar year to derive indicated incurred loss at a 10th report for the LR2 method.

18. **Loss Ratio – Based on Preliminary Selected for Most Recent Three Prior Years (LR3)**

The LR3 method is very similar to the LR2 method, but rather than relying on all preceding accident years within the triangle, relies on at most the preceding three accident years. Thus this method is more responsive to recent loss ratio experience, but potentially more volatile.

19. **Munich Chain Ladder (MCL)**

The MCL method is described by Quarg and Mack in [11]. Similar to the LDF method, discussed above, there are paid (MCL-P) and incurred (MCL-I) versions of the MCL method. In practice, these indications often converge on each other, although the indications are rarely equal. Due to the convergence of the two methods, no adjustment factor is included in the calculation of the MCL-P method, which is distinct from the LDF-P method.

5. REFERENCES

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Abbreviations and notations

|	
ALAE, allocated loss adjustment expense	HS, hindsight outstanding
BRC, backward recursive case development	I, incurred
BT, Benktander	IA, incremental additive
BS, Berquist-Sherman case development	IBNR, incurred but not reported
BF, Bornhuetter-Ferguson	ICC, incremental claims closure
BLS, Brosius least squares	IM, incremental multiplicative
BLSW, Brosius least squares – weighted	LAE, loss adjustment expense
CAS, Casualty Actuarial Society	LDF, loss development factor
CC, Cape Cod	LR, loss ratio
CDF, case development factor	MCL, Munich chain ladder
DCCE, defense and cost containment expense	P, paid
FS, frequency/severity	ULAE, unallocated loss adjustment expense
GIRO, general insurance research organizing committee	

Biographies of the Authors

Susan J. Forray is a Principal and Consulting Actuary in the Milwaukee office of Milliman. She is a Fellow of the Casualty Actuarial Society and a Member of the American Academy of Actuaries. Susan has been active in the Casualty

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Zachary A. Ballweg is a Consulting Actuary in the Milwaukee office of Milliman. He is a Fellow of the Casualty Actuarial Society and a Member of the American Academy of Actuaries. Zach has provided actuarial assistance to a spectrum of risk-bearing entities in both the private and public sectors, ranging from large multi-line commercial insurance companies to self-insured programs. He can be reached at zachary.ballweg@milliman.com.

**Carried Hindsight Development Ratios, Industry Aggregate
by Months of Development
Auto Liability**
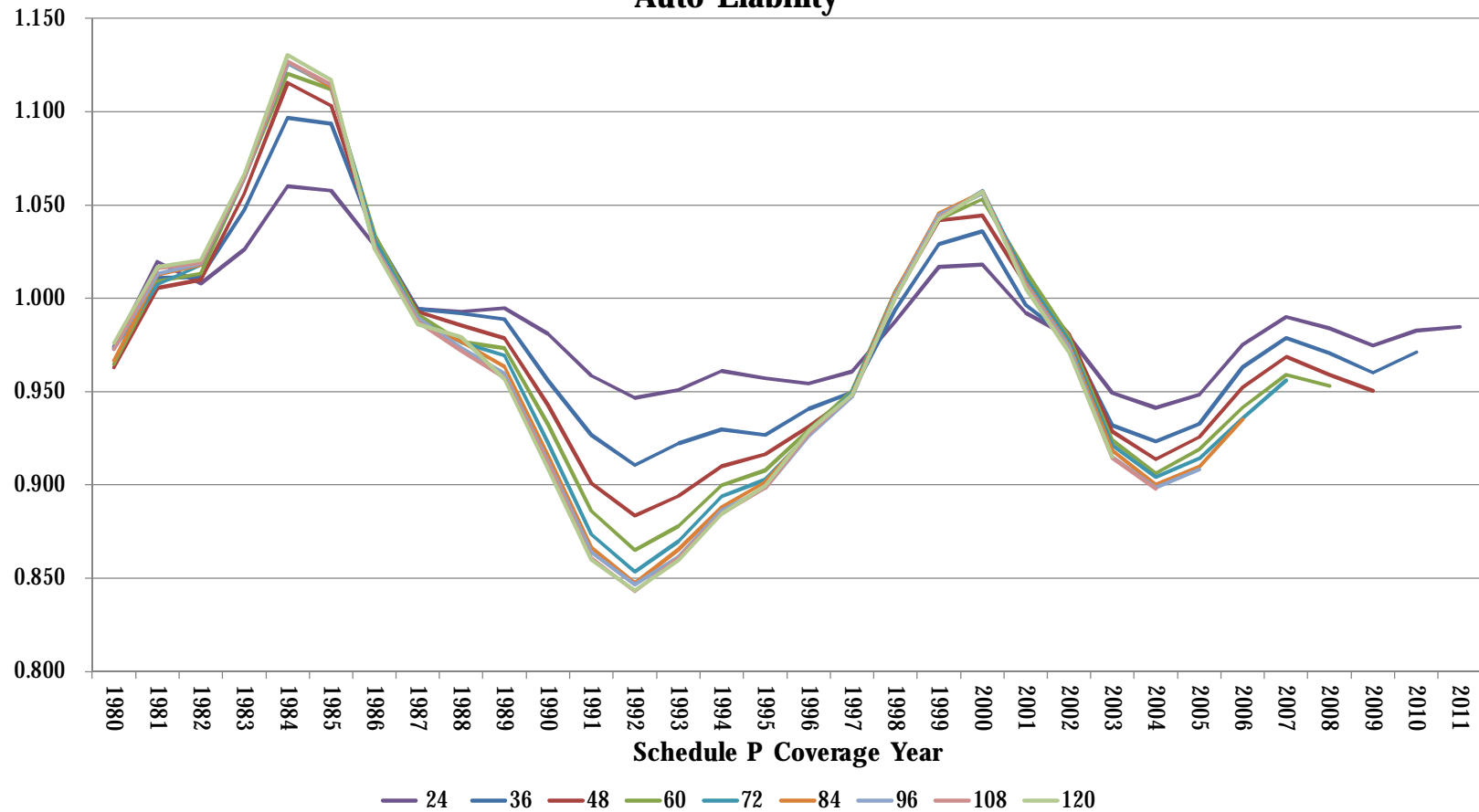
**Carried Hindsight Development Ratios, Industry Aggregate
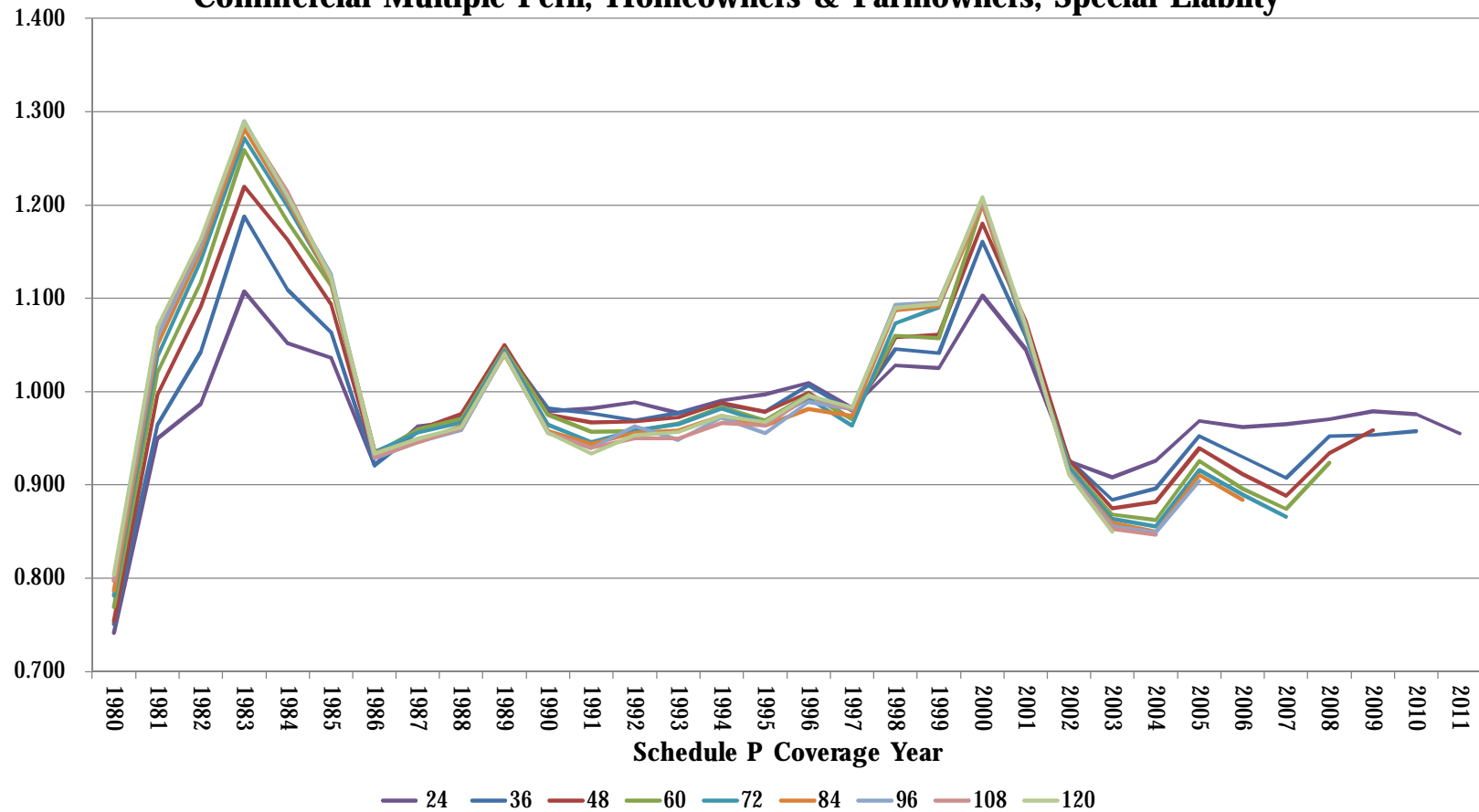by Months of Development
Other Liability**
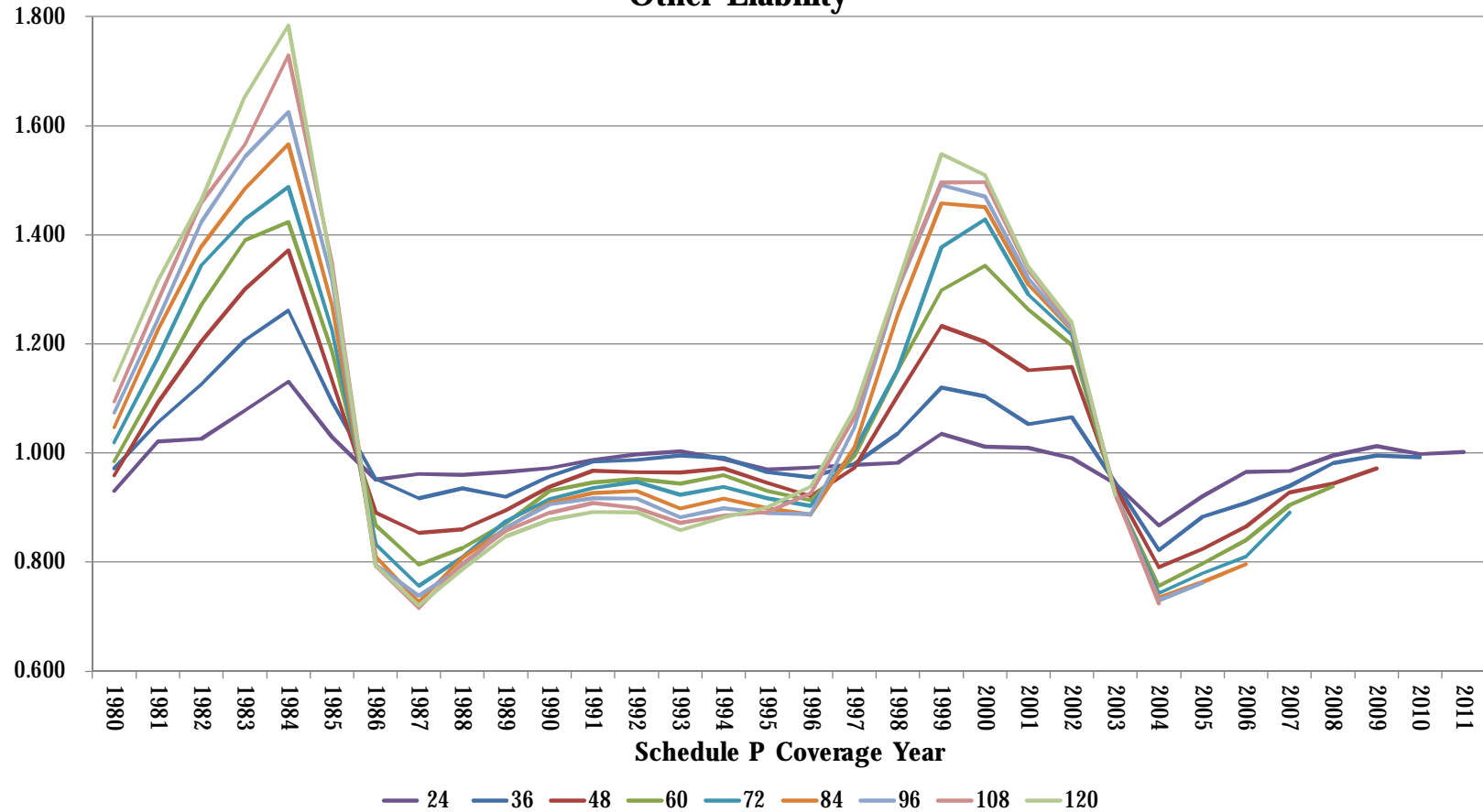
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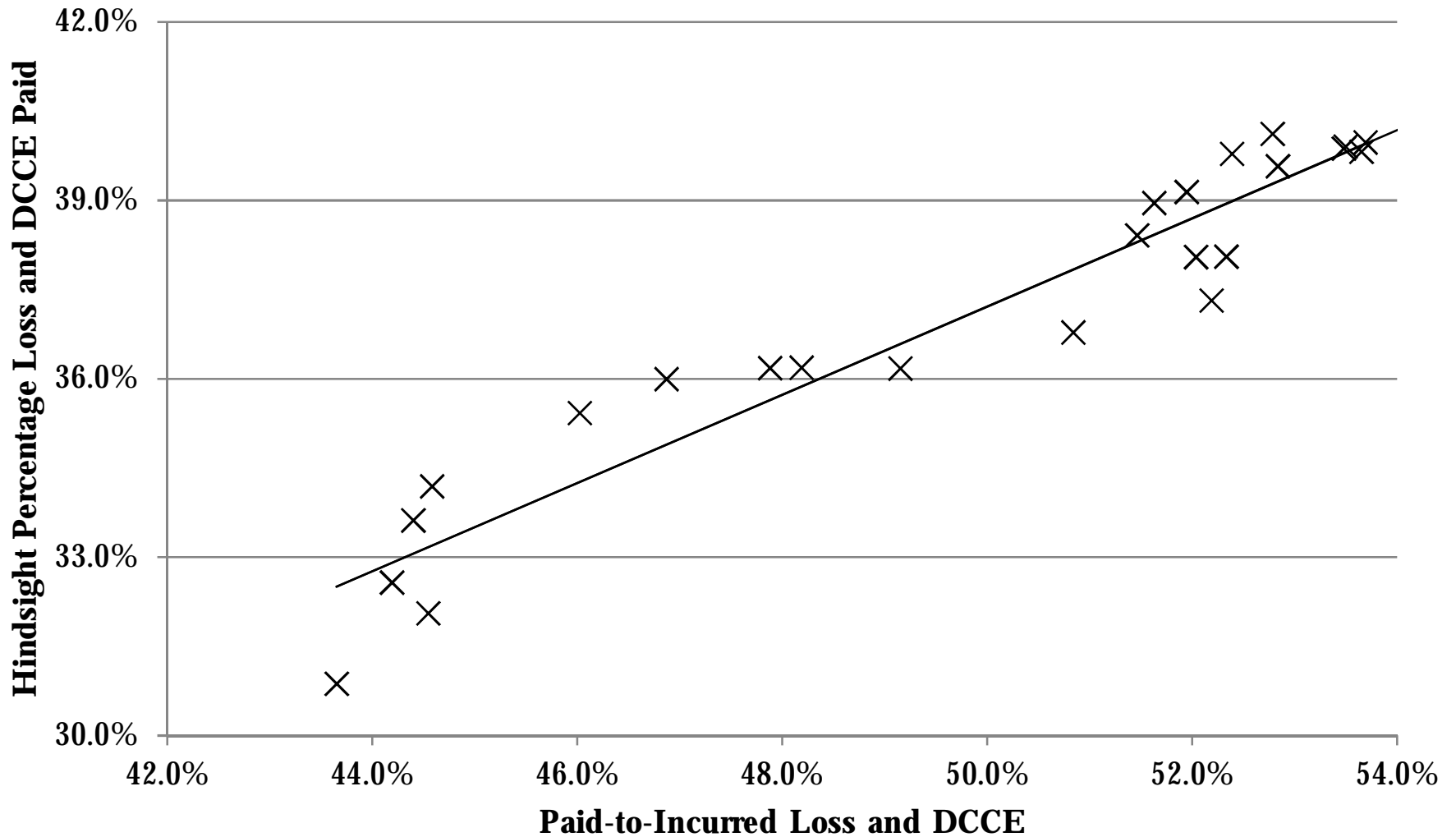by Months of Development
Medical Professional Liability**
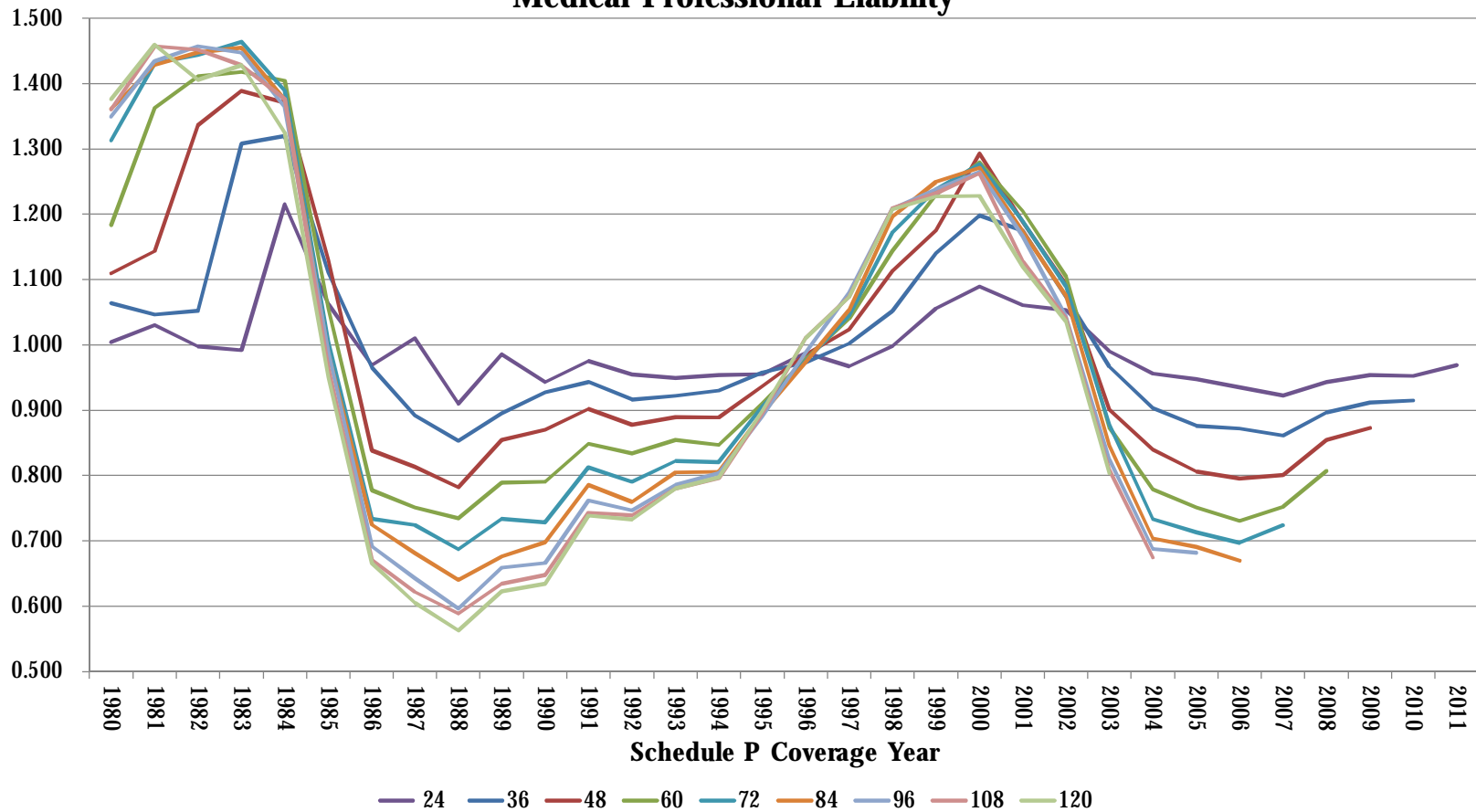
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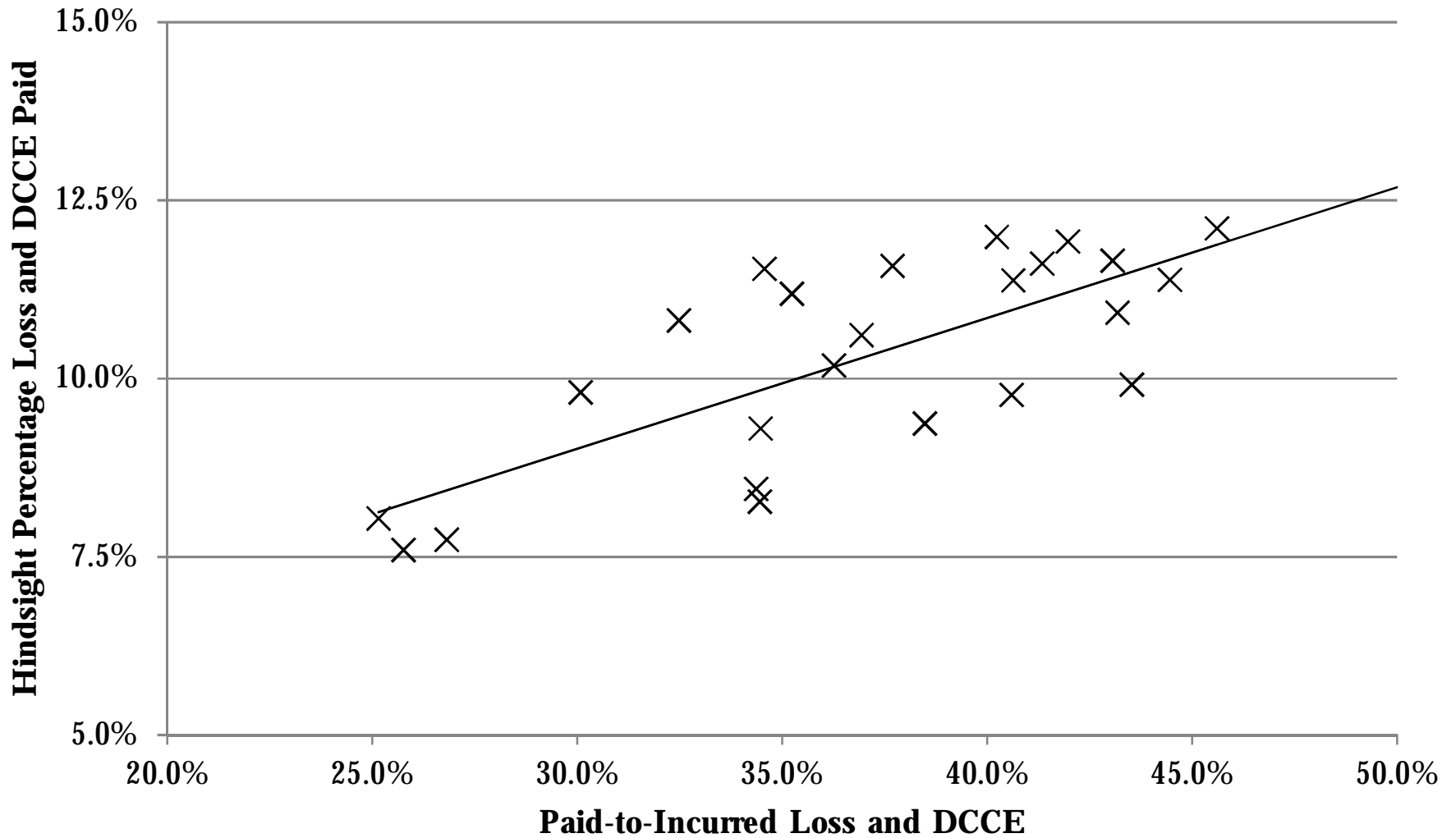by Months of Development
Workers' Compensation
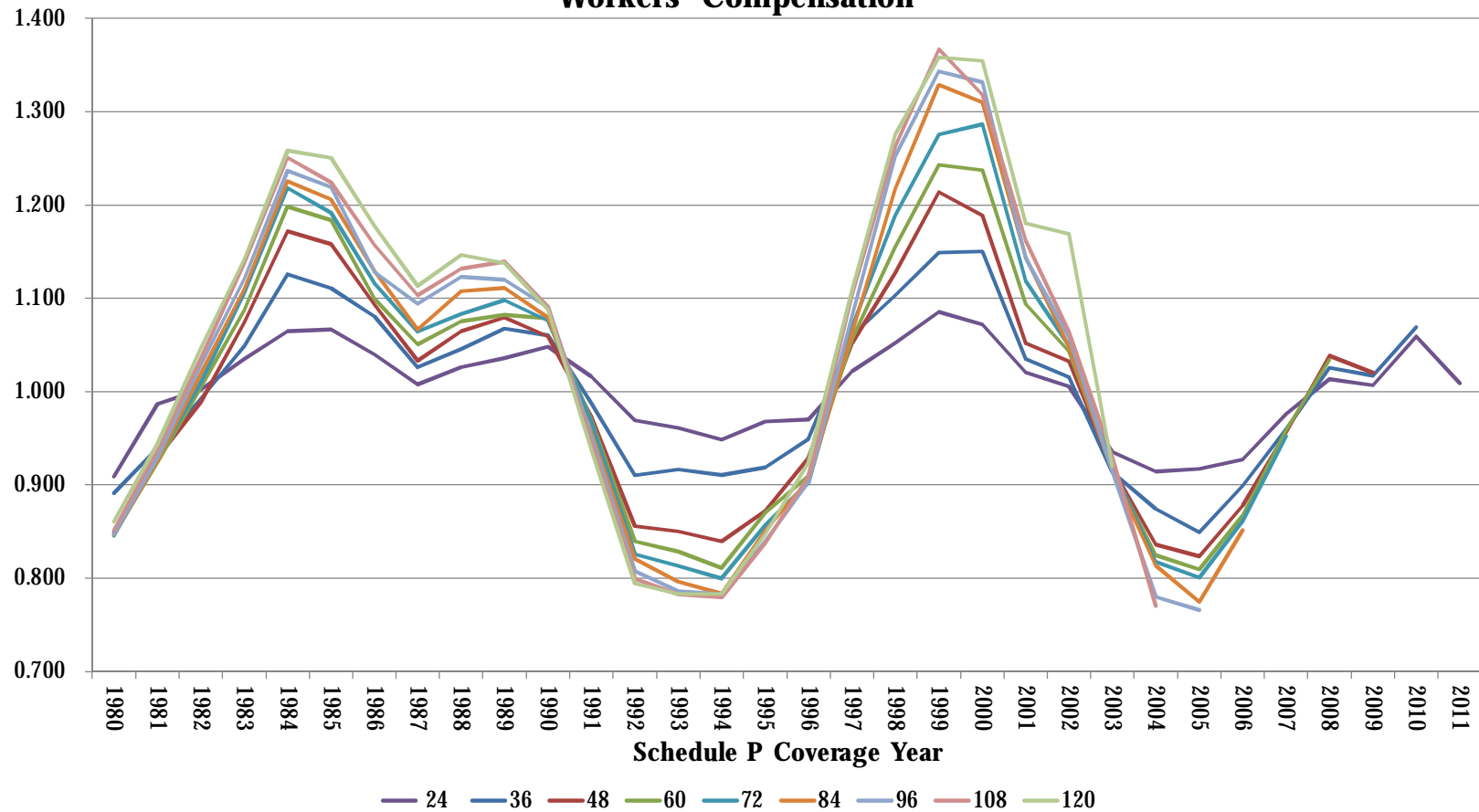
**Carried Hindsight Development Ratios, Industry Aggregate
by Months of Development
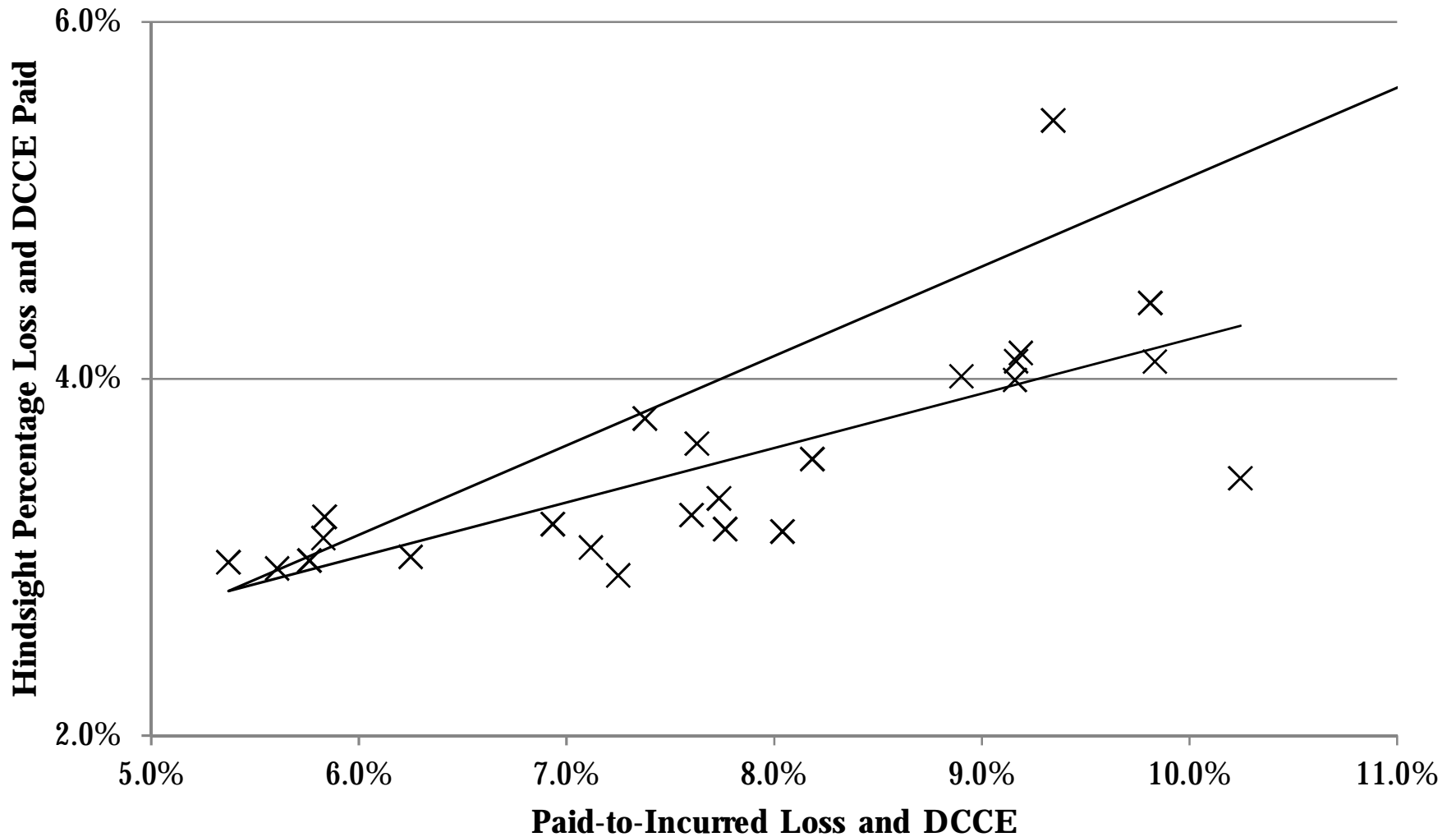Commercial Multiple Peril, Homeowners & Farmowners, Special Liablity**

Paid-to-Incurred vs. Hindsight Percentage Paid
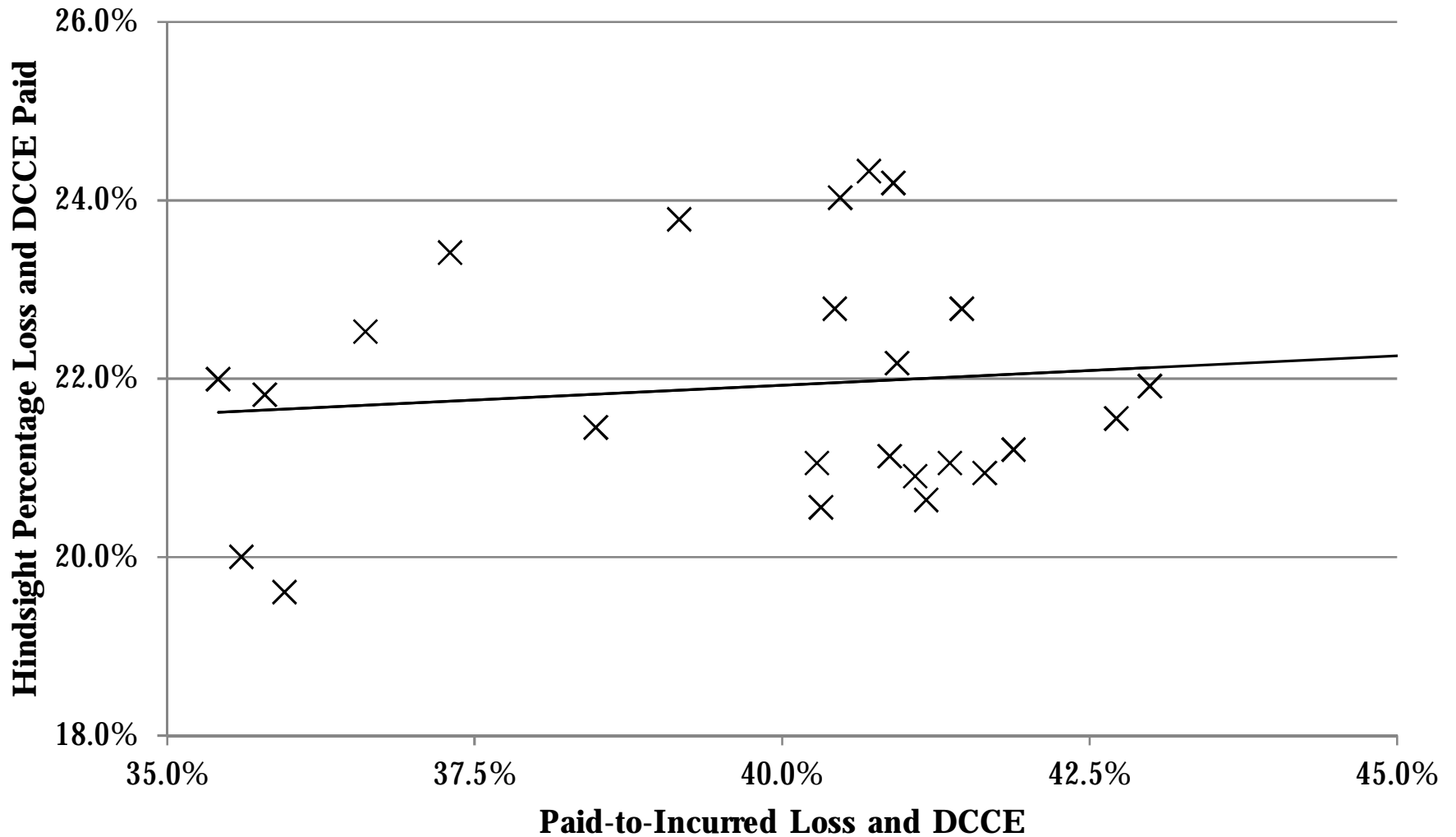**Industry Aggregate**
Auto Liability

Paid-to-Incurred vs. Hindsight Percentage Paid
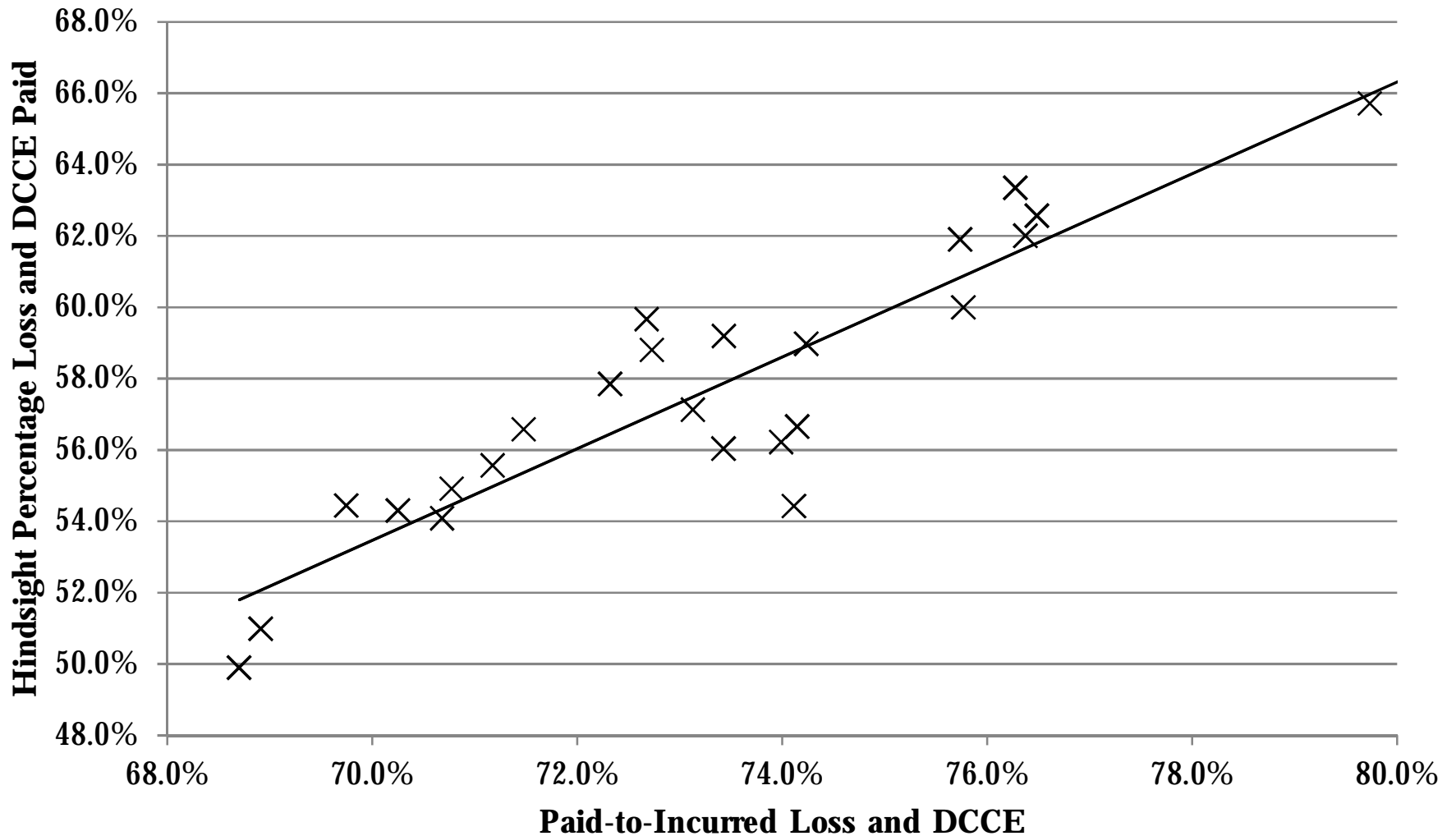**Industry Aggregate**
Other Liability

Paid-to-Incurred vs. Hindsight Percentage Paid
Industry Aggregate
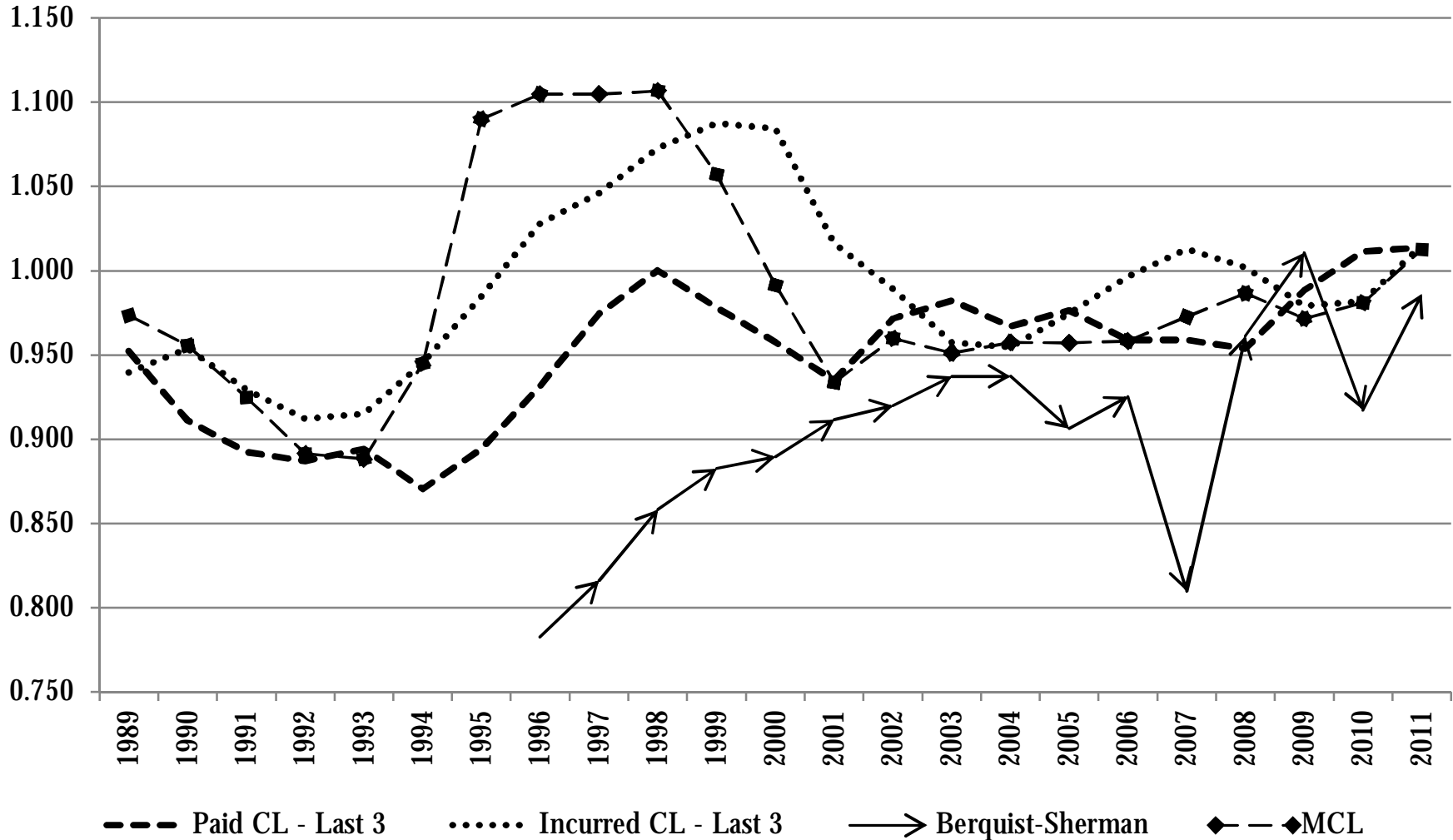**Medical Professional Liability**

Paid-to-Incurred vs. Hindsight Percentage Paid
Industry Aggregate
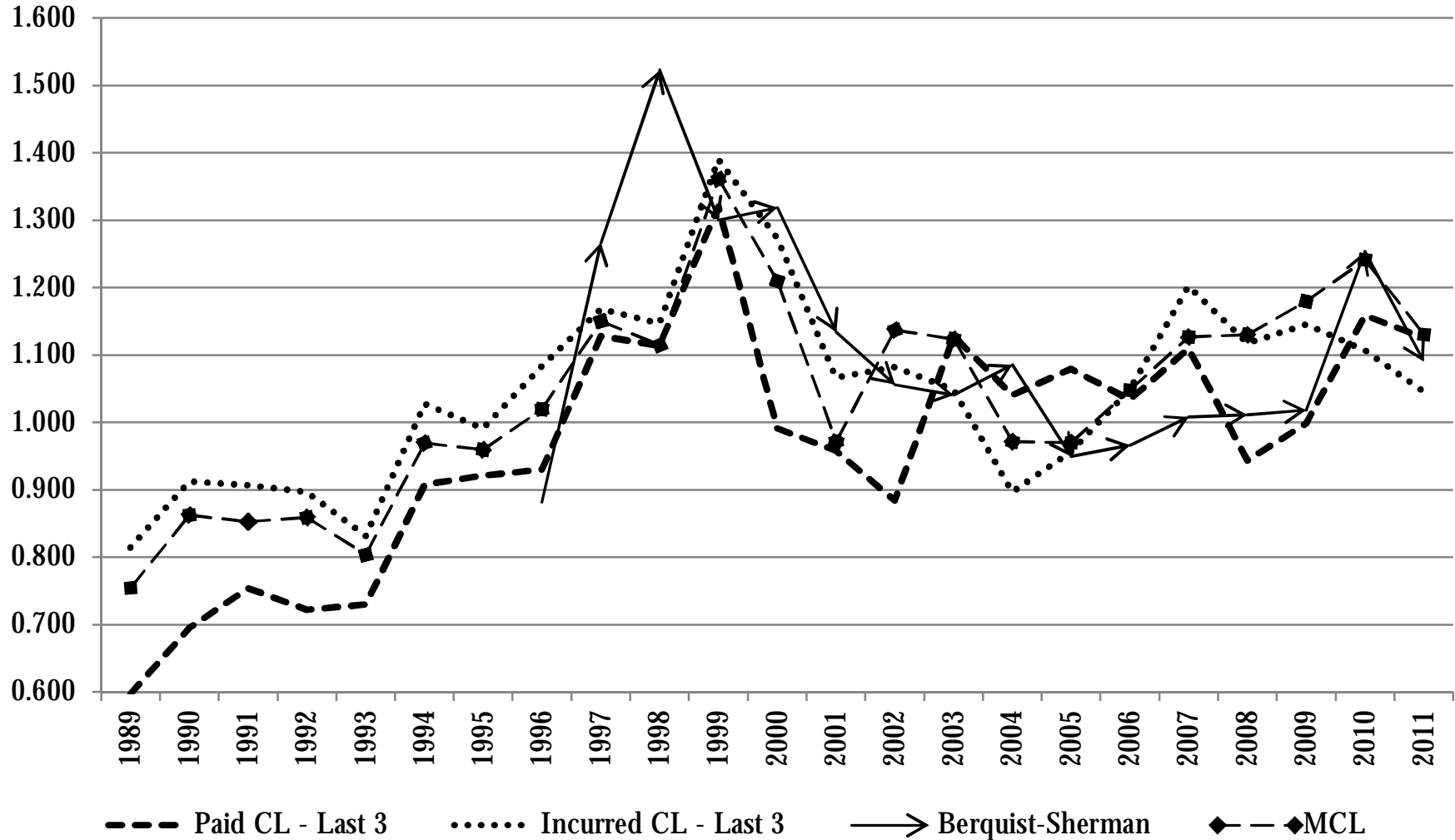**Workers' Compensation**

Paid-to-Incurred vs. Hindsight Percentage Paid
Industry Aggregate
Commercial Multiple Peril, Homeowners & Farmowners, Special Liability

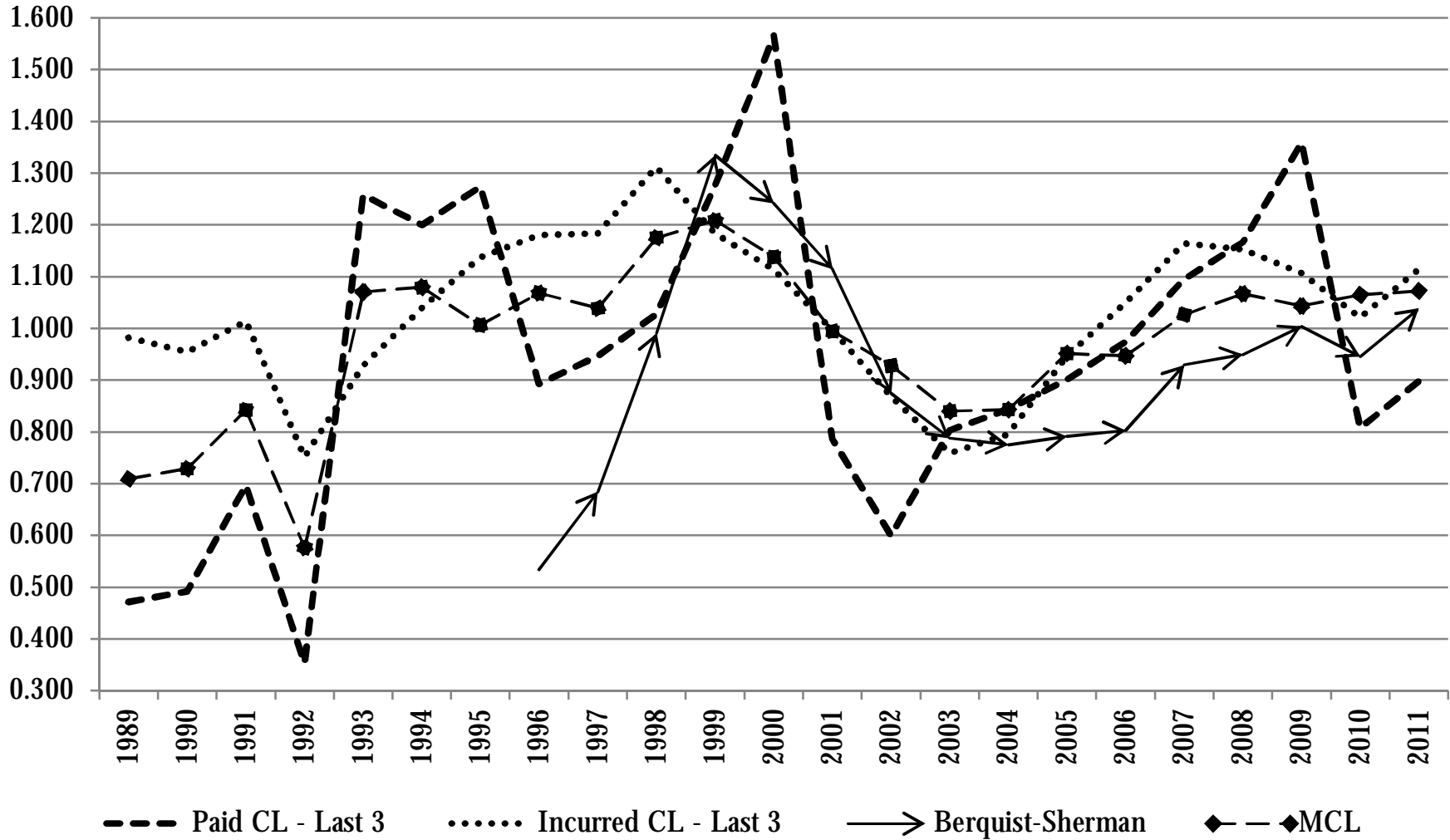## Hindsight Development Ratios, Industry Aggregate
Auto Liability

Hindsight Development Ratios, Industry Aggregate
Other Liability

Legend: Paid CL - Last 3 — Incurred CL - Last 3 ‥‥‥ Berquist-Sherman →— ◆—◆MCL

Hindsight Development Ratios, Industry Aggregate
Medical Professional Liability

Legend: Paid CL - Last 3 · · · · · · Incurred CL - Last 3 ──→ Berquist-Sherman ◆──◆ MCL

Hindsight Development Ratios, Industry Aggregate
Workers' Compensation

- - - Paid CL - Last 3   ・・・・・・ Incurred CL - Last 3   ——→ Berquist-Sherman   ◆ — ◆ MCL

Hindsight Development Ratios, Industry Aggregate
Commercial Multiple Peril, Homeowners & Farmowners, Special Liability

Legend: Paid CL - Last 3   Incurred CL - Last 3   Berquist-Sherman   MCL
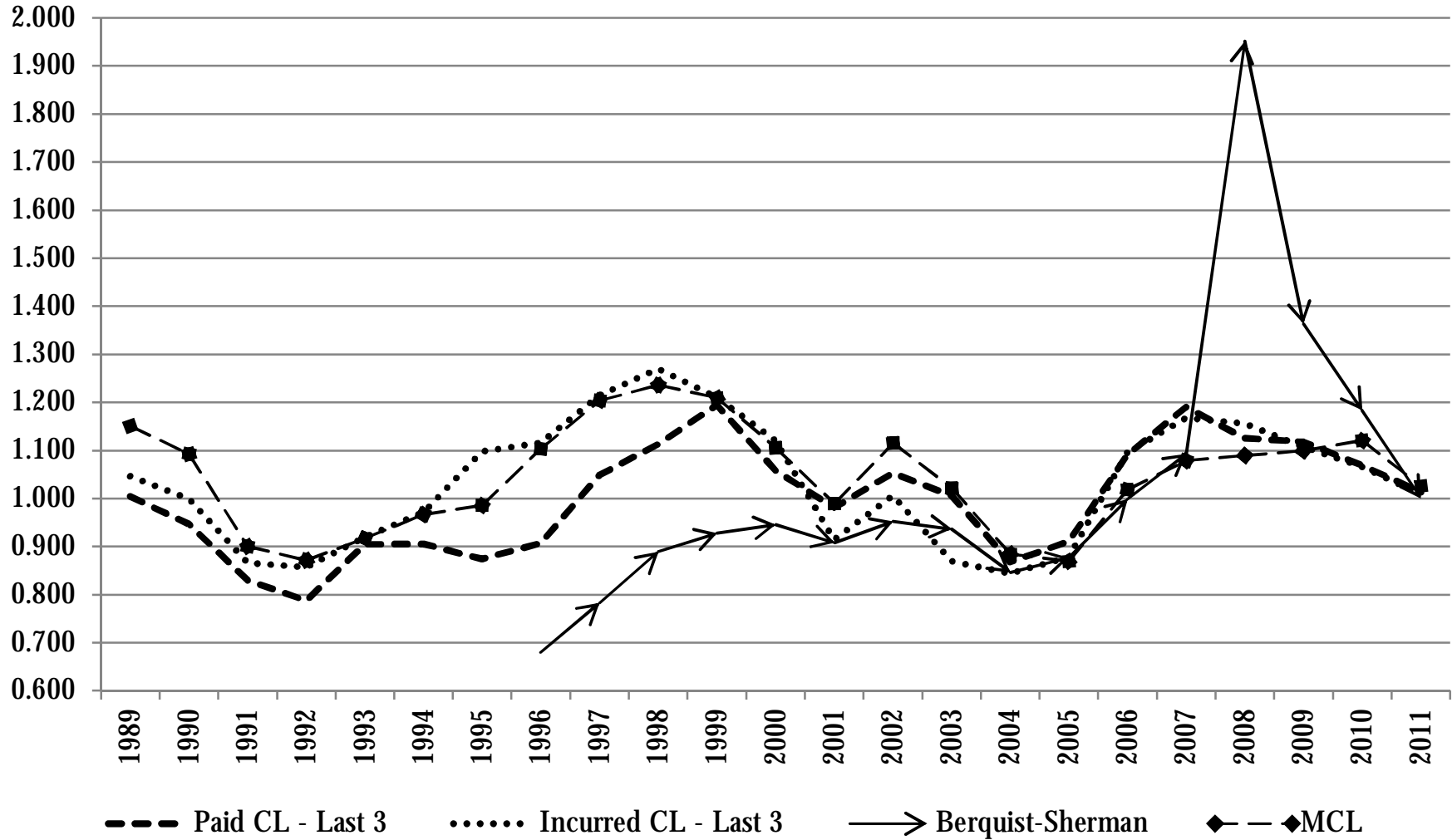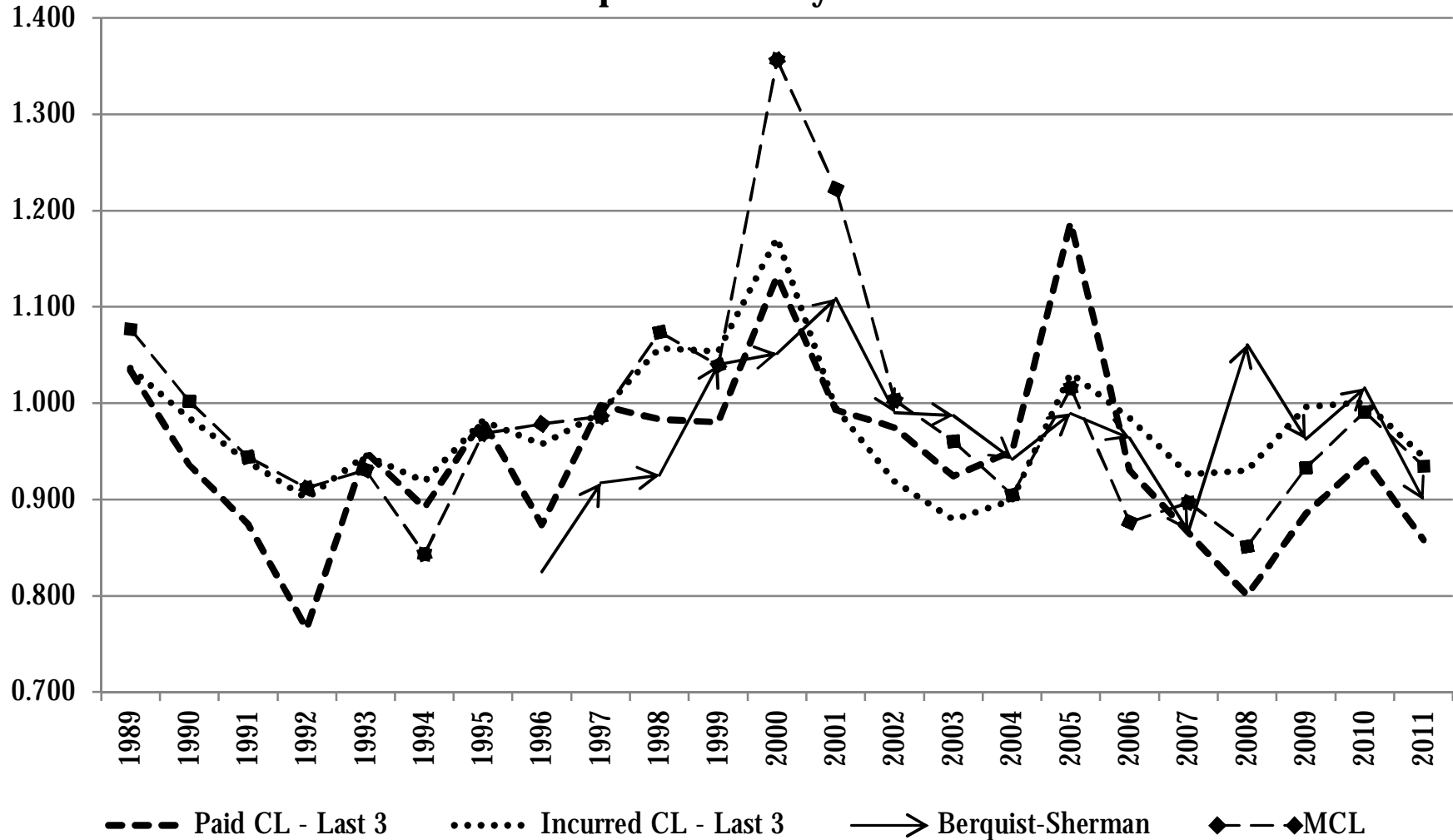
Correlations and R-Squared Values of Hindsight Development Ratios of Carried Unpaid Loss and DCCE and Actuarially Indicated Unpaid Loss and DCCE *Auto Liability*		
Actuarial Method	Correlation	R-Squared
Paid Chain Ladder *	41%	17%
Paid Chain Ladder **	67%	44%
Incurred Chain Ladder *	93%	86%
Incurred Chain Ladder **	85%	72%
Berquist-Sherman	1%	0%
Munich Chain Ladder	44%	19%

*All Years Weighted Average Development Factors

** Three Years Weighted Average Development Factors

Correlations and R-Squared Values of Hindsight Development Ratios of Carried Unpaid Loss and DCCE and Actuarially Indicated Unpaid Loss and DCCE *Other Liability*		
Actuarial Method	Correlation	R-Squared
Paid Chain Ladder *	57%	32%
Paid Chain Ladder **	38%	15%
Incurred Chain Ladder *	81%	66%
Incurred Chain Ladder **	73%	54%
Berquist-Sherman	69%	48%
Munich Chain Ladder	60%	36%

*All Years Weighted Average Development Factors
** Three Years Weighted Average Development Factors

Correlations and R-Squared Values of Hindsight Development Ratios of Carried Unpaid Loss and DCCE and Actuarially Indicated Unpaid Loss and DCCE *Medical Professional Liability*		
Actuarial Method	Correlation	R-Squared
Paid Chain Ladder *	70%	49%
Paid Chain Ladder **	42%	18%
Incurred Chain Ladder *	75%	56%
Incurred Chain Ladder **	52%	27%
Berquist-Sherman	52%	27%
Munich Chain Ladder	68%	46%

*All Years Weighted Average Development Factors
** Three Years Weighted Average Development Factors

Correlations and R-Squared Values of Hindsight Development Ratios of Carried Unpaid Loss and DCCE and Actuarially Indicated Unpaid Loss and DCCE *Workers' Compensation*		
Actuarial Method	Correlation	R-Squared
Paid Chain Ladder *	69%	47%
Paid Chain Ladder **	63%	40%
Incurred Chain Ladder *	93%	86%
Incurred Chain Ladder **	59%	35%
Berquist-Sherman	0%	0%
Munich Chain Ladder	80%	64%

*All Years Weighted Average Development Factors
** Three Years Weighted Average Development Factors

Correlations and R-Squared Values of Hindsight Development Ratios of Carried Unpaid Loss and DCCE and Actuarially Indicated Unpaid Loss and DCCE *Commercial Multiple Peril, Homeowners & Farmowners, Special Liability*		
Actuarial Method	Correlation	R-Squared
Paid Chain Ladder *	26%	7%
Paid Chain Ladder **	40%	16%
Incurred Chain Ladder *	75%	56%
Incurred Chain Ladder **	82%	67%
Berquist-Sherman	34%	12%
Munich Chain Ladder	80%	63%

*All Years Weighted Average Development Factors

** Three Years Weighted Average Development Factors