Some Considerations With Regard To Inflation

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Abstract

The following paper presents and uses a simplified framework to explore the impact of inflation across various aspects of loss reserving, pricing, and capital management. The primary intent is to highlight some general principles which can be used to understand where, how, and by how much inflation risk may affect various aspects of actuarial modeling; but its intent is also to encourage actuaries of the importance in adequately reflecting future expectations of inflation in their models.

Keywords. Inflation; insurance; reinsurance; collective risk model; reserving; ratemaking; capital modeling.

1. INTRODUCTION

Inflation has become a problem again. Relatively stable since the mid-90s, 2009 was officially deflationary for the first time in many countries' post-war histories and future trends are really anybody's guess with fears of hyper-inflation vs. deflation sharply divided across political lines. For hyper-inflation, we have the amount of credit many governments are pumping into the private sector, exchange rates of purchasing economies falling relative to producing economies, and investors hedging bets by purchasing large amounts of more traditional commodities. Also interesting is the theory that rising commodity prices in local currencies are contributing to the 2011 protests in the Near and Middle East as countries inflate their currencies in an attempt to maintain their pegs to the U.S. dollar. For deflation, we have high unemployment which should imply a lower than normal level of wage inflation (even wage deflation), an excess labor supply, property devaluation, decreased expenditure on "luxury" goods, and austerity. And this is just with regards to underlying index inflation—for insurance, material shifts in super-imposed claims inflation (judicial, social, labor, and otherwise) are already contributing to downward pressure on profits in many markets. Not to mention increased utilization of benefits as a result of a weak economy and all its associated problems. While these changing trends can wreak havoc on first-dollar insurance products, the effects can and have historically been catastrophic in higher layers where even the most subtle of shifts may be exacerbated. Given the increased importance of including inflation in actuarial models, the purpose of this paper is to explore and comment on the effect inflation can have on several key aspects of actuarial practice including loss development, dependence, credibility, decreased limits factors, loss distributions, and risk margins. Rather than merely considering the well-documented leveraged impact of inflation, our intention is to present practical results which will help actuaries understand where, how, and by how much inflation could affect their work and, as such, to stress the importance of modifying models to allow for inflation.

2. EXECUTIVE SUMMARY

The purpose of this paper is to explore the effect of inflation across several areas of actuarial practice so as to provide readers with the insight necessary to appropriately understand some of the general effects unexpected future inflation may have on different insured layers. Although the exact effect is totally dependent on each (re)insurer's unique situation—and as such the following results should be considered general under "nice" conditions and not universal in all, "nice" as well as "not-nice," circumstances—we will show the following broad rules-of-thumb:

- ***Leveraged impact of inflation***. The attachment point is the most important variable in determining the leveraged impact of inflation on reinsured layers (i.e., increasing the attachment will increase the impact of inflation) with the limit tempering the effect and co-insurance having no impact.
- ***Decreased limit factors***. Although the amount of experience in excess relative to ground-up or lower layers will typically increase quite quickly with inflation, the uncertainty around such relativities will typically decrease.
- ***Loss development.*** Inflation in excess of that observed historically slows down loss development; conversely, deflation speeds up development. This effect is exacerbated for higher layers of insurance, longer-tailed lines and lines which are characterized by single lump-sum payments rather than those characterized by periodic payments.
- ***Dependence.*** Volatile general inflation affecting all lines increases the dependence between risks whereas volatile super-imposed inflation affecting a single line decreases the dependence between lines.
- ***Loss distributions.*** Although it is obvious that inflation will change the distribution of losses in the insured layers, the key result is that for layers with a reasonable enough amount of experience, increasing the inflation rate will decrease the volatility of loss experience in that layer *relative to the mean*—the implication of this finding is explored in other sections.
- ***Credibility.*** Given a sufficient amount of historical experience by insured layer, inflation should increase the credibility of historical experience.
- ***Risk Margins.*** As inflation increases, the relative risk margin decreases across most insured layers suggesting that risk margins for excess layers are relatively less affected by inflation than the best estimate of total loss or outstanding reserves.

3. METHODOLOGY

3.1 Model

The following results are based on simulation using extensions of the collective risk model. See Klugman et al. [6] for a basic description of the collective risk model. Essentially, for each trial and accident year, we simulated the number of claims based on an assumed frequency distribution. For each claim, we simulated the ultimate loss amount based on an assumed severity distribution. We paid that claim out based on assumed loss development patterns and knowledge of how the claims for certain lines pay (e.g., for liability lines, we primarily relied on lump-sum settlements; for the indemnity portion of workers compensation, we primarily relied on steady payments and so forth). See Butsic [2] for example. We then applied calendar-year inflation trends to the incremental payments. We considered both deterministic as well as stochastic inflation to assess the impact of increasing amounts of inflation as well as increasing uncertainty in future inflation, respectively. As a result, many of the results are delineated as being from the "deterministic scenario" or from the "stochastic scenario."

The above is easily enough programmed into most computer languages and the Casualty Actuarial Society's (CAS) Public Loss Simulation Model contains much of the functionality required to explore these results further. In many situations, especially when trying to get reasonable parameter estimates in higher layers, this process can become quite time-consuming and the importance of efficient simulation and more complex techniques such as stratified sampling become necessary.

3.2 Parameterization

We present most of our results in terms of the following broad excess of loss (XOL) layers—ground-up, lower, working, and excess. To make the examples as consistent as possible, we set the lower layer, or retention, at a level where approximately 90% of the loss prior to inflation would fall. Similarly, we parameterized the working layer with the next 7.5% of the loss and then the excess layer with the final 2.5% of the loss. We also used several other splits, such as 75/15/10 and 95/3/2, to sensitivity test our results. Further, we parameterized our results using industry benchmark data and sensitivity tested the results using varying assumptions and parameters across several different lines of insurance.

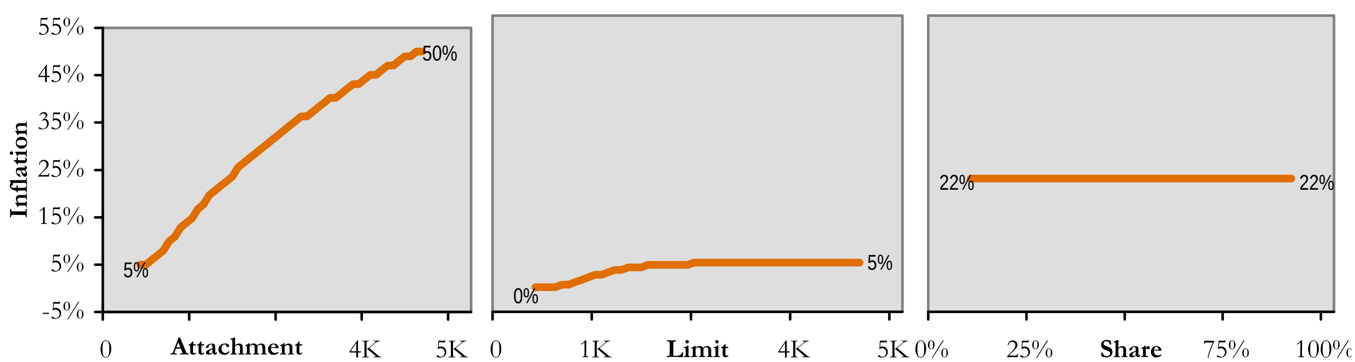
3.3 Caveats

We note that there are several caveats to our work. First, although we did attempt to sensitivity test our results to various parameterizations, lines of business, and reinsurance contracts, the infinite permutations make it impossible to present truly universal results using this type of empirical analysis. Therefore, it is important that these results only be considered general and used for reasonability checks or as an aid in assumption setting when the exact effect in the actuary's unique situation can not be determined. Further, we note that in addition to the above, our analysis tended to rely on "nice" situations—medium-sized books of business with homogenous claim profiles coupled with reasonable reinsurance contracts. It will often be the case that reinsurance contracts do not satisfy these nicety conditions and "kinks" will arise in the results. This further indicates the importance of modeling each unique situation. As a continuation of the above, we tended to use ”nice” continuous loss distributions without consideration of binary or CAT-type events which may further distort the results. Although, in any event, the effect of inflation on these types of events should be analyzed by event scenario rather than in aggregate.

4. DETAILED FINDINGS AND CONCLUSIONS

4.1 Leveraged impact of inflation

The leveraged impact of ground-up trends on higher layers is a well-documented phenomenon in actuarial literature. See for example Lange [6]. Essentially the theory shows that ground-up trends such as inflation are intensified in higher layers of insurance as small increases to ground-up losses result in relatively larger increases to losses within the layer. This effect is most pronounced for losses that were expected to fall below the attachment point and now trend into the excess layer as a result of inflation. For losses which have already or nearly exhausted the limit the effect is tempered and the impact of inflation on such losses can be minimal. Figure 1 below provides a simple illustration of this leveraged impact. Each panel shows the impact of 5% ground-up inflation on an excess layer reinsurance product by varying a single term of the contract.



(a) By Attachment (Unlimited) (b) By Limit (No Attachment) (c) By Share (1K xs 1.5K)

Figure 1. Leveraged impact of inflation (5%) for varying attachment, limit, and share.

Although shown in a very specific environment, these relationships will hold true in most situations and help illustrate four general principles with regard to (re)insurance and inflation. Namely, that (1) as the attachment increases from zero to unlimited, the expected layer inflation increases from the ground-up inflation rate to a theoretically unlimited amount (although in practice, for most reasonable excess layers, the leveraged inflation will appear to stabilize asymptotically at some large amount); (2) as the limit increases from zero to unlimited the layer inflation increases from 0% to the ground-up inflation rate; (3) the share does not affect inflation; and (4) the dominant determinant of the leveraged impact of inflation is the attachment point with the effect dampened by the limit. While the relative magnitude and exact impact are of course unique to any situation, these four principles can be used to help understand the general impact of inflation on most general (re)insurance contracts.

4.2 Decreased limits factors

The purpose of this section is to address the relationship between inflation and increased limits factors (ILFs)/decreased limits factors (DLFs). Specifically, we show that although, as would be expected from the prior section, deterministic inflation increases the DLF for excess layers, deterministic inflation decreases the volatility around that DLF. We also show that the effect of stochastic inflation on the DLF will often be negligible.

4.2.1 Some background on increased limits factors

In his 1977 paper, "On the Theory of Increased Limits and Excess of Loss Pricing," Robert Miccolis does an excellent job of developing simple mathematical formulas, still widely used today, for setting increased limits factors (ILFs). His approach is "moment-based" whereby the ILF is set equal to the ratio of the expected value of losses in layer A to the expected value of losses in layer B. Unfortunately, this approach results in a deterministic ILF as the expectation of a random variable is a fixed rather than variable quantity. As such, to answer the question as to whether inflation affects the volatility of the ILF, we rely on a stochastic variant of this deterministic ILF, namely the ratio of losses in layer A to losses in layer B prior to expectation. Although this quantity is not as useful in practice, it does provide a reasonable approximation under nice conditions and will allow us to address whether or not there is a leveraged impact of *uncertainty* as well as a leveraged impact of inflation.[1]

4.2.2 The relationship between inflation and DLFs — deterministic scenario

Figure 2 plots the 95th percent confidence interval around the working and excess layer DLFs computed using increasing amounts of deterministic inflation. Note that as expected, the DLF for these upper layers increases with the inflation rate, i.e., more losses trend into the layer. However, as the DLFs of the lower, working, and excess layers must by definition sum to 100%, it will not always be the case that both the working and excess layers DLFs will increase. A more universal comparison would be the lower layer vs. a single upper layer where the lower layer DLF will always

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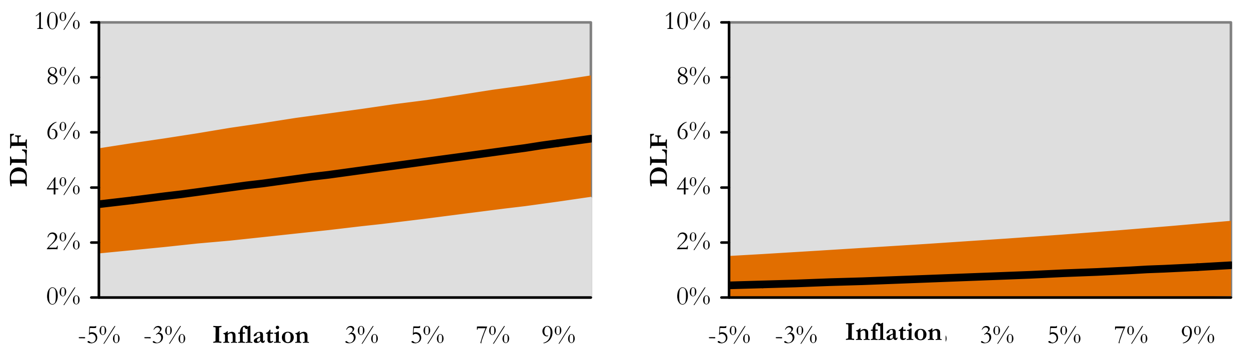
[1] Namely, we conjecture that if aggregate losses are modeled using the collective risk model then the expectation of the ratio of losses in layer A to losses in layer B (i.e., E[A/B]), where A is a subset of the losses in B, will tend to the ratio of expectations (i.e., E[A]/E[B]) for sufficiently large number of independent and identically distributed insureds/claims.

decrease due to the effect of the upper limit and the upper layer DLF would always increase. In the case of multiple upper layers, it is possible that the DLF for one or more upper layers may actually decrease given the right relationship of reinsurance terms and loss distribution. That aside, more importantly note that increasing the underlying inflation rate does not appear to impact the volatility of the DLF. In fact, although not obvious from the graphs, the volatility actually decreases *relative* to the mean in these examples. This will commonly be the case as while inflation increases the losses in the layer, the reinsurance terms will "squeeze" the losses in the layer.



(a) Working layer

(b) Excess layer

Figure 2. Confidence interval around estimates of the working and excess layer DLFs for increasing levels of deterministic inflation.

4.2.3 The relationship between inflation and DLFs — stochastic scenario

In the case of stochastic inflation, the effect of increasing the volatility of ground-up inflation on both the best estimate DLF as well as uncertainty around the best estimate is generally somewhat negligible. As will be discussed in more detail in the section on loss distributions, the exact direction and amount of the effect is dependent on several, often contra-directional, changes to the volatility and mean of the underlying frequency and severity distributions determined by the relationship between the reinsurance terms and the loss distribution before and after the application of stochastic inflation. And at the end of the day, the effect becomes somewhat immaterial. Figure 3 helps to demonstrate these results plotting the DLF and funnel of doubt for various levels of volatility.

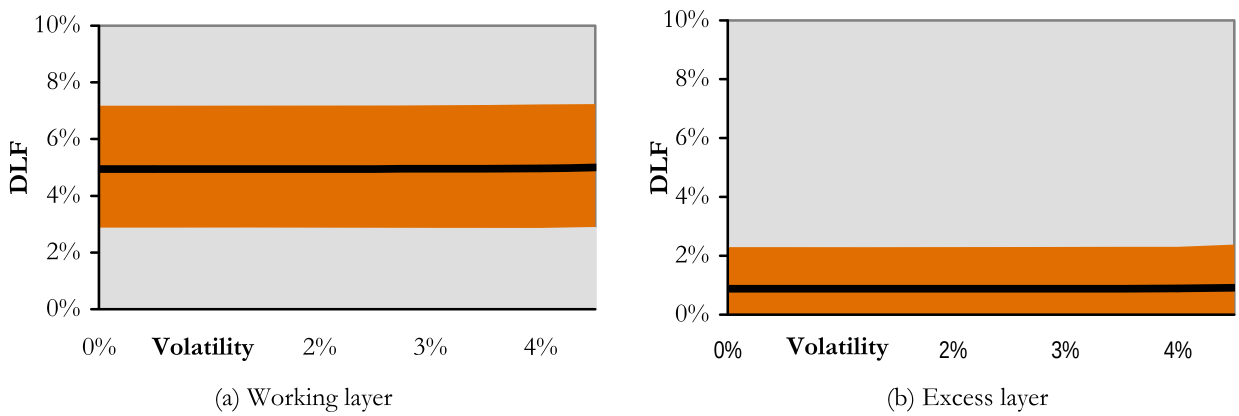


Figure 3. Confidence interval around estimates of the working and excess layer DLFs for increasing levels of stochastic inflation volatility keeping expected inflation constant at 5%.

4.2.4 Going forward

The most interesting conclusion of this section is that while the leveraged impact of inflation can be significant, if we can develop an adequate expectation as to future inflation, and incorporate it into our models as such, then we can usually develop a good understanding of future reinsurance losses— even if they are considerably larger than they have been historically.

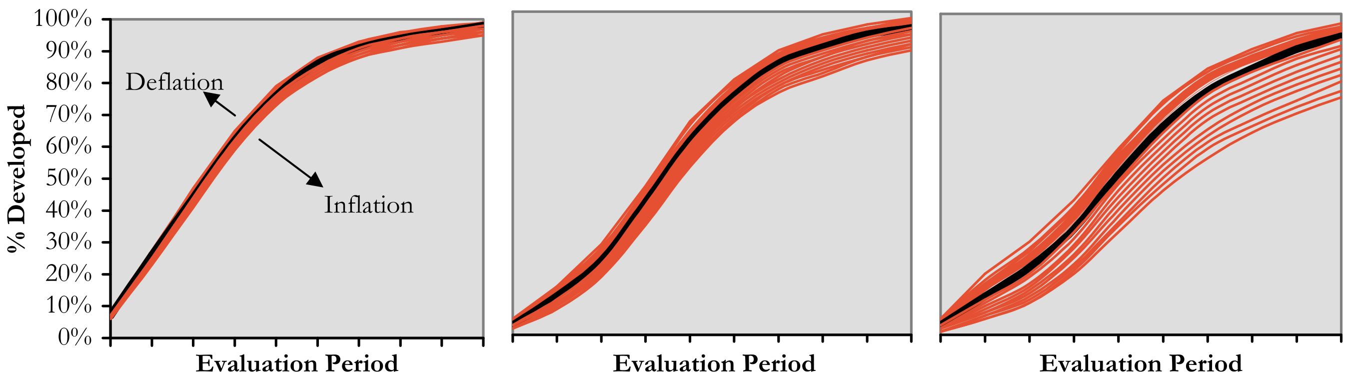
4.3 Loss development

The purpose of this section is to discuss the relationship between inflation and loss development. Primarily, we show that inflation in excess of that observed historically slows down loss development and, conversely, deflation speeds up development. This effect is exacerbated for higher layers of insurance, longer-tailed lines, and lines which are characterized by single lump-sum payments (i.e., liability lines) rather than those characterized by periodic payments.

4.3.1 The relationship between inflation and development— by reinsurance layer

Calendar year inflation which is consistent from year to year will not impact the accuracy of loss development methodologies (i.e., the chain-ladder method). This is shown more explicitly in Boles et al. [1], but can be understood by noting that loss development methodologies, by virtue of taking the ratio of losses from one period to the next, cancel out the impact of calendar year inflation in the numerator and denominator. That said, loss reserving methods which aren't 'development' methodologies all have to make some adjustment for inflation. Often this involves trending forward incremental amounts, adjusting the IELRs and so forth. But still, assuming the inflation is steady, and the adjustment is reasonable, the accuracy of these methods isn't affected.

However, it is when the inflation rate changes abruptly and materially, that our estimates of ultimate loss and unpaid claim liabilities will be distorted. Inflation in excess of that shown historically will slow down development patterns and inflation less than that shown historically will speed up development patterns. Like the leveraged impact of base inflation, these impacts are also considerably more leveraged in excess layers of insurance. This is illustrated in Figure 4 which plots the first 10 years of the cumulative paid pattern in each of the lower, working, and excess layers. The dark black reference line indicates the pattern with historical inflation removed. The lines above this reference line show the development pattern with increasing magnitudes of deflation; and the lines below show the development pattern with increasing magnitudes of inflation.



(a) Lower (b) Working (c) Excess

Figure 4. Effect of inflation on loss development for various insured layers.

4.3.2 The relationship between inflation and development—by type of pattern

Not only is there a leveraged distortion on development in higher layers, the amount by which the pattern is distorted very much depends on the time of pattern. Taking the working layer as an example, Figure 5(a) compares the error[2] in the chain-ladder method for a short-tailed, medium-tailed, and long-tailed line of business and various levels of inflation. As expected, the long-tailed line is significantly more affected than the shorter-tailed lines as the distortion compounds with inflation at the later evaluations. Figure 5(b) compares the error in the chain-ladder method for a line of business primarily characterized by periodic payments (i.e., workers compensation indemnity) vs. a line of business primarily characterized by single lump-sum payments (i.e., medical malpractice). Note that development for the periodic payment class is much less affected than development for

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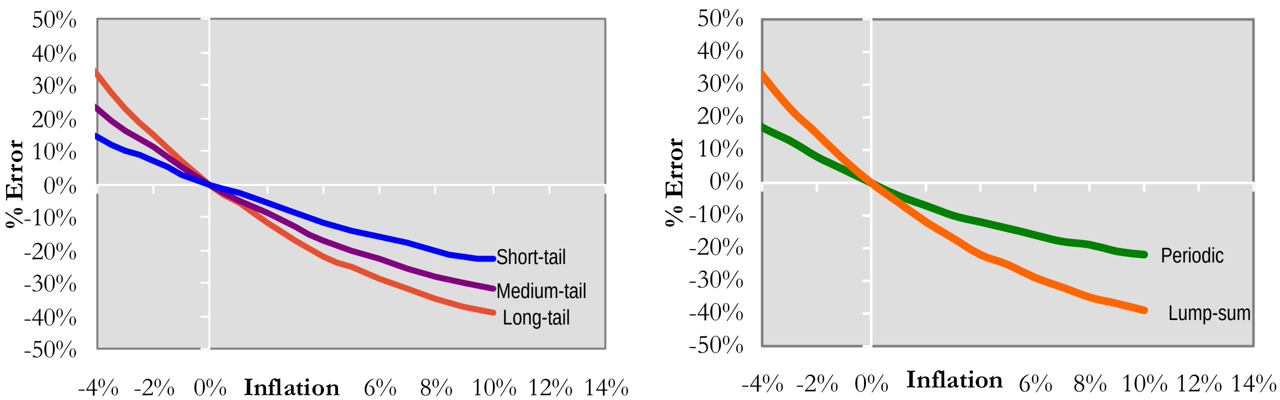
[2] Here, error specifically refers to the expected estimate of ultimate loss less the actual ultimate loss divided by the actual ultimate loss.

the lump-sum class as lump-sums at later maturities bear the full-brunt of inflation whereas with periodic payments only a portion of the total claim is adjusted for inflation at these later maturities minimizing the overall impact on development. Both of these results imply that as the duration increases, so does the distortion.



(a) Length of tail

(b) Primary type of payment

Figure 5. Effect of unexpected inflation on various types of patterns.

4.3.3 Going forward

Of all the results shown in the paper, loss development, and the projection of ultimate loss, is the one most sensitive to the exact conditions. The degree to which a pattern slows down (or speeds up in the case of deflation) is significantly dependent on whether the data is short-tailed or long-tailed, how losses are paid, the degree to which inflation is present in historic data, the exact policy limits, the size of the book, and so forth. To this end, and especially as inflation departs from its historical norm, it is necessary to utilize reserving methodologies which both make an implicit or explicit adjustment for historical inflation as well as allow you to incorporate your own actuarial judgment as to future inflation into the projections.

4.4 Dependence

This section considers the relationship between inflation and dependence. We show that with regard to general economic inflation affecting all lines simultaneously, increasing the volatility of inflation will increase the dependence between lines. Conversely, with regard to specific by-line inflation affecting only a single line, increasing the volatility of inflation will decrease the dependence between lines. Finally, we note that here the key driver of these results is the volatility of inflation rather than the actual inflation rate.

4.4.1 Inflation, dependence, and systemic vs. non-systemic risk

To understand these results, it is necessary to first take a step back and examine the relationship between inflation and dependence. Specifically, that it is not the magnitude of the expected inflation which matters, but rather it is the uncertainty around that expected magnitude. Without going into the mathematics, it is perhaps easiest to frame the problem by considering dependence as a function of the amount of systemic risk relative to the non-systemic risk. When the amount of systemic risk is substantially larger than the amount of non-systemic risk, dependence will generally be high as the systemic risk dominates and vice versa. Thus, by increasing the volatility of inflation which is exogenous to both lines of insurance, we are in turn increasing the amount of systemic risk relative to non-systemic risk and increasing the dependence between lines. On the other hand, by increasing the volatility of inflation for a single line, we are increasing the amount of non-systemic risk relative to systemic risk and as such decreasing the dependence between lines. While the direction is predictable, the rate at which the dependence changes depends on the initial ratio of systemic to non-systemic risk which is highly susceptible to the interrelationship between the reinsurance terms and the underlying frequency and severity distributions. As such, it will not always be the case that the dependence by layer changes in an ordered manner with predictable rates of change.

4.4.2 The relationship between inflation and dependence—general inflation

Figure 6 shows how inflation can change the dependence between lines by plotting the correlation[3] between two lines in the scenario where general monetary inflation affects both lines simultaneously. Figure 6(a) shows the effect of increasing the inflation rate in the deterministic scenario and Figure 6(b) shows the effect of increasing the volatility of inflation in the stochastic scenario. In order to emphasize our findings, we started with two lines which were independent of one another and then added inflation. First note that in the case of varying the degree of deterministic inflation, there is no effect as fixed inflation does not distort the degree of systemic vs. non-systemic risk. However, as we increase the volatility of general economic inflation, the correlation between lines increases as the systemic risk increases relative to the non-systemic risk. Although the direction of the change is fairly easy to assess, the magnitude of change is quite difficult to predict without actually modeling the specific scenario.

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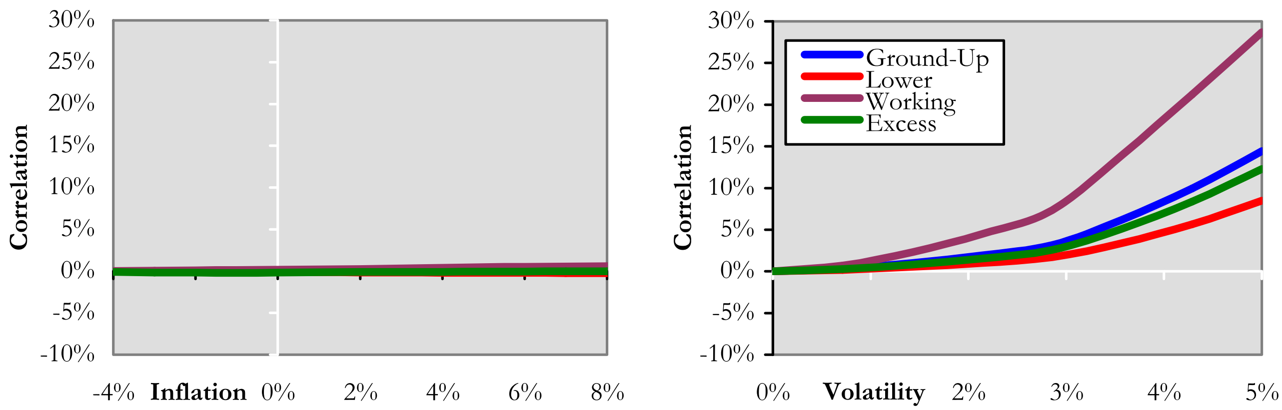
[3] As an aside, note that while we use correlation as our measure of dependence in this section, the correlation measure is not without its weaknesses and using such a measure to assess dependence may not always be appropriate.

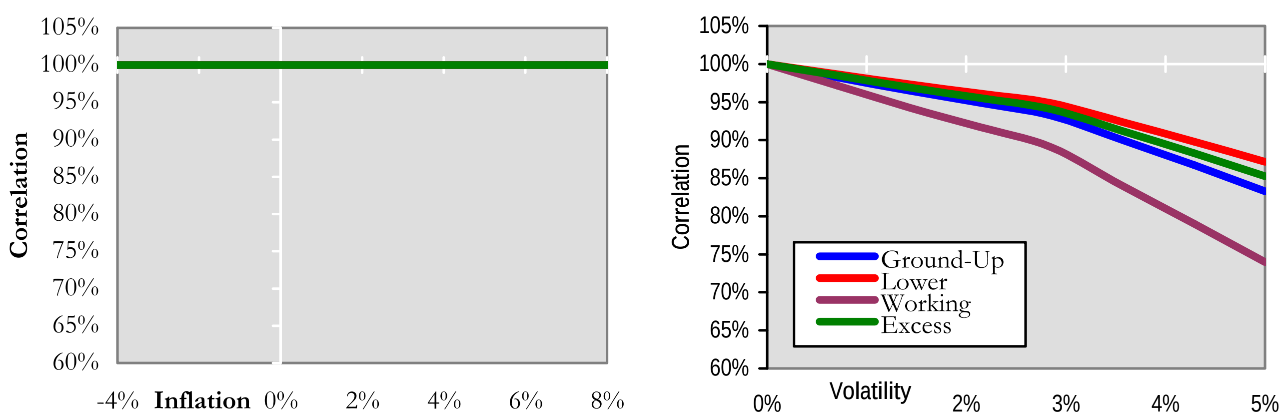


(a) Deterministic Scenario (b) Stochastic Scenario

Figure 6. Effect of general inflation on dependence by layer for various inflation rates and volatilities.

4.4.3 The relationship between inflation and dependence – specific inflation

Now, while the above results refer to the situation where inflation impacts several lines of insurance simultaneously, Figure 7 shows how specific by-line inflation affecting a single line, will decrease the dependence between lines. Figure 7(a) shows the effect of increasing the inflation rate in the deterministic scenario and Figure 7(b) shows the effect of increasing the volatility of inflation in the stochastic scenario. In order to emphasis our findings, we started with two lines which were perfectly correlated and then added inflation to one line. Again note that varying the level of deterministic inflation has little effect; but, with regard to varying the volatility of the inflation parameter, we see that the correlation between lines quickly decreases as the amount of non-systematic risk increases relative to the systemic risk.



(a) Deterministic Scenario (b) Stochastic Scenario

Figure 7. Effect of specific by-line inflation on dependence by layer for various inflation rates and volatilities.

4.4.4 Going forward

These results are nothing new, in fact they are the basis of the Marshall-Olkin copula structure and often used for introducing dependence among independent events in actuarial science through the form of a "contagion" parameter in the collective risk model. See Klinker et al. [6] for example. However, they are not always considered when setting correlation assumptions resulting in capital models which may mis-specify the amount of dependence and degree of risk between lines.

4.5 Loss distributions

Like loss development, the effect of inflation on loss distributions by layer is highly speculative and depends primarily on the interaction between the reinsurance terms and the ground-up distributions. However, there are a few obvious effects—inflation will cause both the mean frequency in the upper layers and the severity in all layers to increase. While inflation will typically cause the volatility of frequency in the upper layers to increase, the effect of inflation on the volatility of severity in the upper layers is less definite and depends primarily on how much room losses in the layer have to play (i.e., is it a tight or wide layer). With regard to ground-up experience, the volatility of the severity distribution will increase with inflation; and in the lower layer, the volatility of the severity distribution will decrease with inflation. More interesting though is the effect inflation has on the volatility *relative to the mean* by insured layer. With regard to both frequency and severity in the upper layers, the CV will typically decrease as inflation increases. Although this is by no means always the case, it will generally be the case when the upper layers insure a non-insignificant share of the loss (i.e., 5% is cutting it close, 10% is getting safer). Typically, the more loss experience there is in a layer, the more likely it is that the CV will decrease with inflation as the loss experience will be more stable and less likely to be affected by large loss "pops." Table 1 below summarizes these points. We have attempted to illustrate confidence in the result by using a scale of one to three arrows for not confident to very confident with a question mark indicating no confidence in making an assessment.

	Frequency			**Severity**		
Layer	**Mean**	**SD**	**CV**	**Mean**	**SD**	**CV**
Ground-up	No change	No change	No change	↑↑↑	↑↑↑	No change
Lower	No change	No change	No change	↑↑↑	↓↓↓	↓↓↓
Working	↑↑↑	↑↑	↓	↑↑↑	?	↓*
Excess	↑↑↑	↑↑	↓	↑↑↑	?	↓*

*Mostly depends on size of layer relative to loss.

Table 1. Effect of increasing **deterministic** inflation on underlying frequency and severity distributions by layer.

Figure 8 illustrates these same points graphically by focusing on the aggregate loss distribution and plotting the probability density for various amounts of inflation. With regards to the ground-up distribution, note that the "location" of the density changes substantially, while the "shape" of the density appears to change only slightly for the various levels of inflation. This makes sense considering the effect of inflation on the component frequency and severity as described above. While inflation does not affect the frequency distribution, it does increase the mean of the severity distribution (i.e., change in location) and although it does increase the standard deviation of the distribution it doesn't change the volatility relative the mean (i.e., similar shape). However, with regard to the upper layers (excess layer is pictured) note that the shape of the distribution, as well as location, changes substantially with inflation as would be indicated by the above.

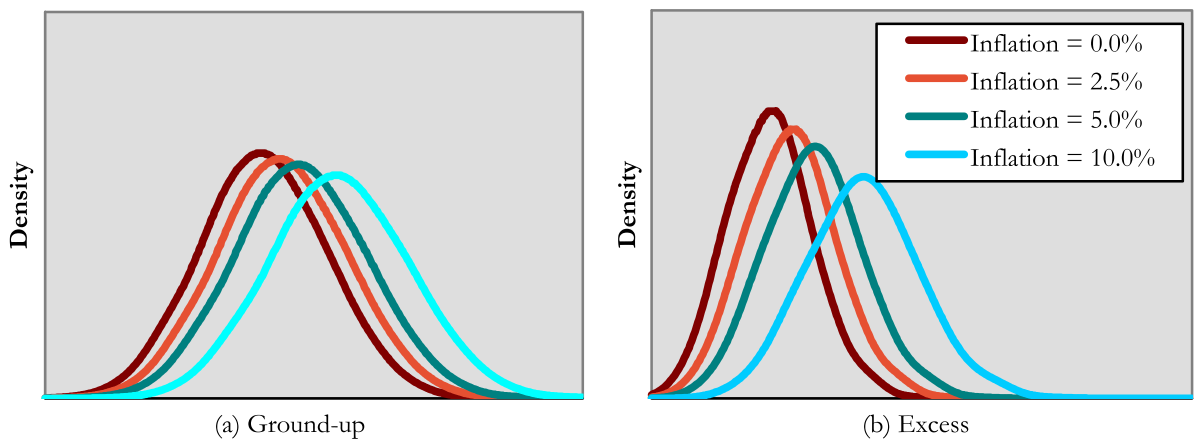


Figure 8. Shift in aggregate distribution due to various inflation scenarios.

These results are too broad for implementation in a specific situation, but are quite useful as an intermediate step for framing the following sections and so we have included them for completeness.

4.6 Credibility

The purpose of this section is to discuss the relationship between inflation and credibility as it relates to historical loss experience. Primarily, we show that (1) in the case of deterministic inflation, as the inflation rate increases, the credibility of ground-up experience will remain unchanged, but the credibility of experience by layer will increase; and that (2) in the case of stochastic inflation, as the amount of volatility increases, the credibility of ground-up experience will decrease although the change in credibility of experience by layer is typically minimal.

4.6.1 Some background on credibility

Without going into too much detail, credibility is the actuarial concept which refers to the amount of weight which should be assigned to historical experience. One of the most common credibility frameworks is Bühlmann credibility which gives the credibility weight as function of three different components—the amount of historical data, the variance of the hypothetical means (VHM) and the expected value of the process variance (EVPV). The relationship of the first component, the amount of data, on credibility is rather obvious in that as the amount of historical data increases so does the weight one should assign to it. For simplicity and without loss of generality, we consider just a single year of experience. The latter two components, the EVPV and the VHM, are rather more difficult to conceptualize, but are excellently illustrated in Steve Philbrick's 1981 paper. "An Examination of Credibility Concepts," in which he draws an analogy with marksmen shooting at targets. However, for our current purposes, it is more useful to think of these concepts within the framework of the collective risk model. Here, the EVPV is primarily driven by the variability in the size of losses (i.e., the coefficient of variation or CV for severity) and the VHM is primarily driven by the variability in the number of claims (i.e., the variance-to-mean ratio or VTM for frequency).

Consider first the EVPV. As the variability in the size of losses increases, the EVPV also increases, but the credibility of actual experience decreases. To understand this, consider the following example: if losses aren't variable and we observe a loss of $1,000, we can be 100% certain that all losses are $1,000. However, if losses are extremely variable and we observe a loss $1,000, we don't actually know if other losses are $1,000 or $1,000,000. In Philbrick's language, the more variability in losses, the more the targets overlap with one another and so with any one observation we are not very confident from which archer it came.

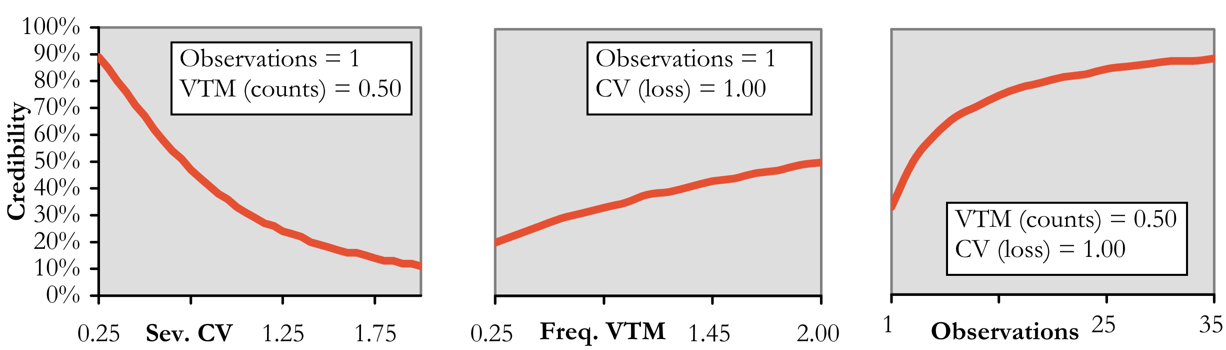
Consider next the VHM. Now, as the variability in the number of claims increases, the VHM also increases and so does the credibility of actual experience. This relationship is a little bit more difficult to understand as it is somewhat counterintuitive, but consider the following example: suppose there is either 1 claim or 100 claims and that the cost per claim is about $50. If we observe aggregate losses of about $50 we can be pretty sure that the number of claims is 1 and if we observe aggregate losses of about $5,000 we can be pretty sure that the number of claims was 100. However, if the number of claims is either 9 or 11 and we observe aggregate losses of $500, we really don't know whether the number of claims was 9 or 11. In Philbrick's language, the more variability in the number of claims there is, the further apart the targets are pushed so that with any one observation we can be more confident in which target the marksmen is aiming at.

Table 2 summarizes these relationships. Note that by re-framing the EVPV and VHM in terms of the key statistic—CV for severity and VTM for frequency—we can easily utilize the results from section 4.5 to explain how changes in the inflation rate might be expected to impact the credibility of historical data.

Driver	Credibility Component	Key Statistic	Credibility
Variability of losses increases	EVPV ↑	CV of severity	↓
Variability of the number of claims increases	VHM ↑	VTM of frequency	↑
Number of observations increases	N ↑	N/A	↑

Table 2. Drivers of credibility.

Figure 9 highlights these relationships graphically. Panel (a) shows that as the CV of the severity distribution increases, the credibility decreases. Panel (b) shows that as the VTM of the frequency distribution increases, so does the credibility and Panel (c) shows that as the number of observations increases, so does the credibility of historical experience. Note that the relationship between each of these components and the credibility is in no way linear and is different for each component. This implies that the exact credibility depends very much on the relationship between attachment and limit as well as the interaction between these terms and the underlying frequency and size-of-loss distributions.



(a) By CV of Loss (b) VTM of claim counts (c) By number of observations

Figure 9. Drivers of credibility.

4.6.2 The relationship between inflation and credibility—deterministic scenario

Figure 10 highlights the effect of increasing the rate of inflation on the credibility for the lower, working, and excess layers. Note that we have also included a black reference line on each graph to show the impact of credibility on the ground-up experience. With regard to ground-up experience, changing the rate of inflation does nothing to impact the credibility of historical data; whereas the credibility by layer increases with the rate of inflation. To some extent, these results make sense when considering layered (re)insurance contracts. The higher the inflation rate, the more losses we would expect to trend into upper layers and increase the amount of experience from which to project from. Further, this additional experience would act to stabilize the "attritional" component of losses in the layers relative to the "large" or "catastrophic" components. And finally, the higher the inflation, and without any indexation of limits and attachment, the more we would expect the reinsurance terms to come into play.

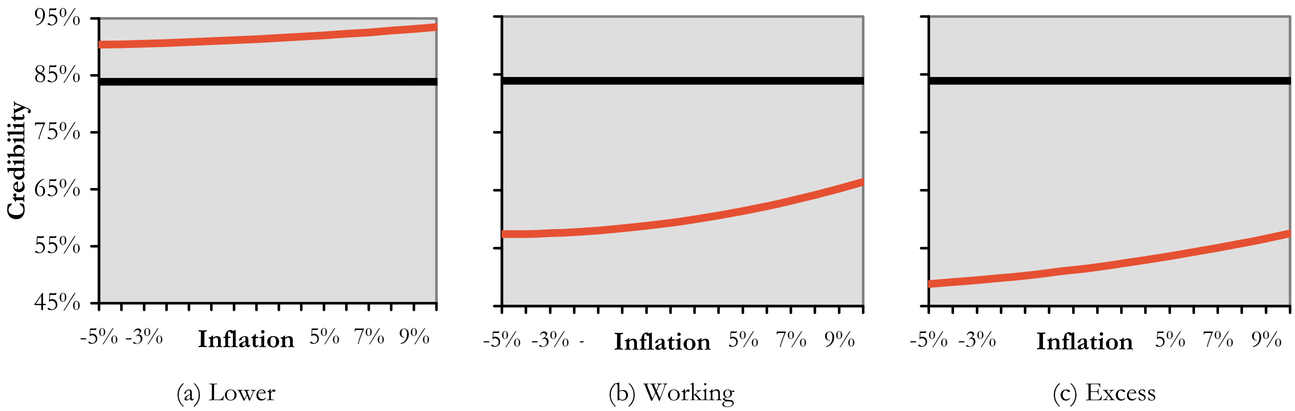


Figure 10. Effect of deterministic inflation on credibility by layer.

However, that said, it is also easy to understand these results with reference to how inflation changes the distribution of the frequency and severity components by layer, keeping both Table 1 and Table 2 in mind. Ground-up deterministic inflation will not change the underlying frequency and severity distribution and thus there is no impact on the credibility of experience. In the lower layer, although there is no change to the frequency distribution, the severity CV will decrease as inflation increases causing the credibility of experience to increase. In the upper layers, the effect is not so certain, but most typically, when these layers have a sufficient amount of experience, the severity CV will decrease with inflation causing the credibility of experience to increase. And although in the upper layers there is also a shift in the frequency distribution, this "frequency" effect is most often dominated by the "severity" effect and can be considered less material.

4.6.3 The relationship between credibility and inflation—stochastic scenario

With regards to stochastic inflation, the results by layer are not nearly as nice. It is first easiest to note that the credibility of ground-up experience will decrease with increased volatility in the inflation parameter as the underlying coefficient of variation for the severity distribution will increase. This result would be expected as the more variable historical experience is, the less we will rely on it. With regards to the insured layers, the effect of inflation volatility on credibility is harder to predict. In general, the credibility will decrease although the exact change is quite uncertain. *However*, as the magnitude of the change will usually be quite small, increased volatility of the inflation parameter is not as worrying.

4.6.4 Going forward

Perhaps the key implication from this section is that for lines with high inflation we should probably be giving more weight to more recent years' experience; whereas, where the claims inflation is largely uncertain, we should primarily rely on a longer history of data smoothing the results out based on long-term averages.

4.7 Risk Margins

The purpose of this section is to discuss the relationship between inflation and the risk margin. In a deterministic setting, we show that increasing the rate of inflation will actually lead to a lower relative risk margin[4] for most layers of reinsurance. With regard to stochastic inflation, we note that the effect of changing the volatility of inflation will most often be negligible.

4.7.1 Some background on risk margins

The risk margin is generally defined as the amount in excess of expected loss which is added as a load to reasonably compensate for the risk associated in an insurance contract. There are a many ways to measure the risk margin, each with their own properties and advocates, but some of the most common measures include the standard deviation (SD), semi-deviation (Semi-SD), value at risk (VaR), and conditional tail expectation (CTE). Because there is no best measure of risk, a standard of "coherence" is often ascribed to those risk measures which possess some desirable characteristics—namely monotonicity, sub-additivity, positive homogeneity, and translation invariance. Here we consider positive homogeneity in detail as it will help frame the effect of

[4] Here, risk margin refers to the percentage multiplicative load rather than a nominal additive load. While inflation will increase the nominal amount of risk margin, it will decrease the relative risk margin as a percentage of the mean.

inflation on risk margins. Simply put, positive homogeneity states that if the insured exposure grows by some percentage q, then our risk also grows by that same percentage q. Theoretically, this property makes sense—if we double the size of a portfolio, the risk should also double. Although, as we will discuss, this property, at least on the face of it, does not hold in the case of inflation.[5]

4.7.2 The relationship between inflation and risk margins—deterministic scenario

If we let q represent inflation, then for a given risk measure we might expect that 5% inflation would increase our estimate of risk by 5%. And if we were to apply a fixed inflation factor to aggregate losses by layer, this certainly would be true. However, with regard to non-proportional reinsurance, the policy terms absorb some of the inflation shock and in turn limit the increase in risk margin. In short, while the insurable exposure gets q% bigger, the risk associated with that exposure only gets $(q\text{-}\varepsilon)$% bigger. This implies that when considering the effect of inflation, the mean is substantially more leveraged than the risk associated with the mean. Figure 11 demonstrates this phenomenon. For comparison purposes, this figure normalizes the risk margin relative to the risk margin with no inflation in each of the layers as indicated by the cross-hairs. Here, the effect is most pronounced for the excess layer and almost negligible for the lower layer.

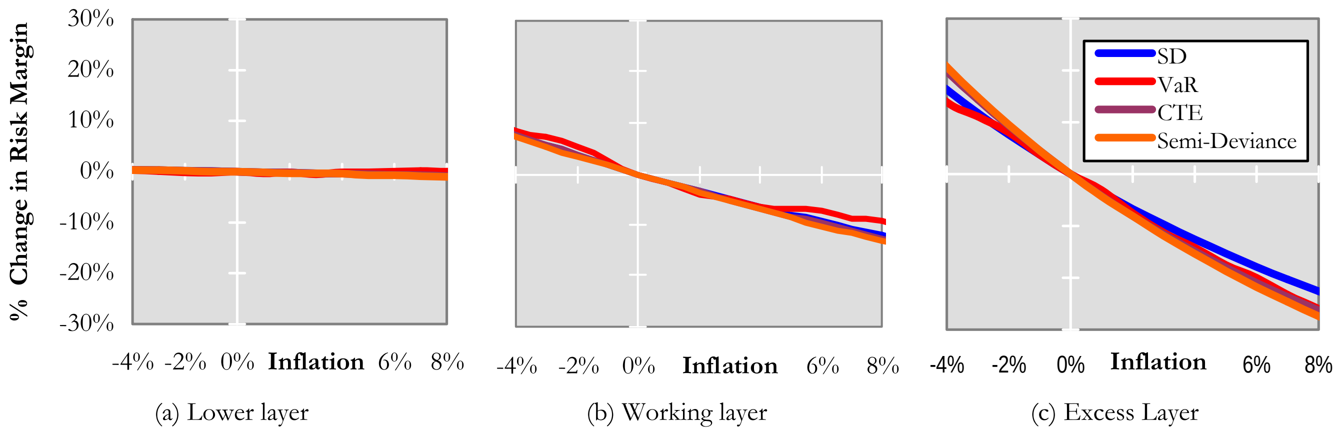


Figure 11. Percentage change in risk measure for increased levels of inflation (measured relative to no inflation).

4.7.3 The relationship between inflation and risk margins—stochastic scenario

The results with regard to stochastic inflation are less straightforward although the magnitude of results will not usually be that material. In this specific situation, Figure 12 shows that the risk

[5] Technically, positive homogeneity does hold in this situation; however, it only appears to not hold because by modelling inflation on a per-occurrence basis and subjecting each loss to the reinsurance terms of the layer we are in effect distorting the distribution rather than just "doubling the exposure base."

margin decreases as the volatility of inflation increases. This will not always be the case (i.e., the risk margin could increase) with the exact result depending on the relationship between the mean and volatility of losses in the layer relative to the reinsurance terms before and after the stochastic inflation is modeled. However, note that here as well as in most situations, the relative magnitude of the effect will be rather negligible both in relative and nominal terms.

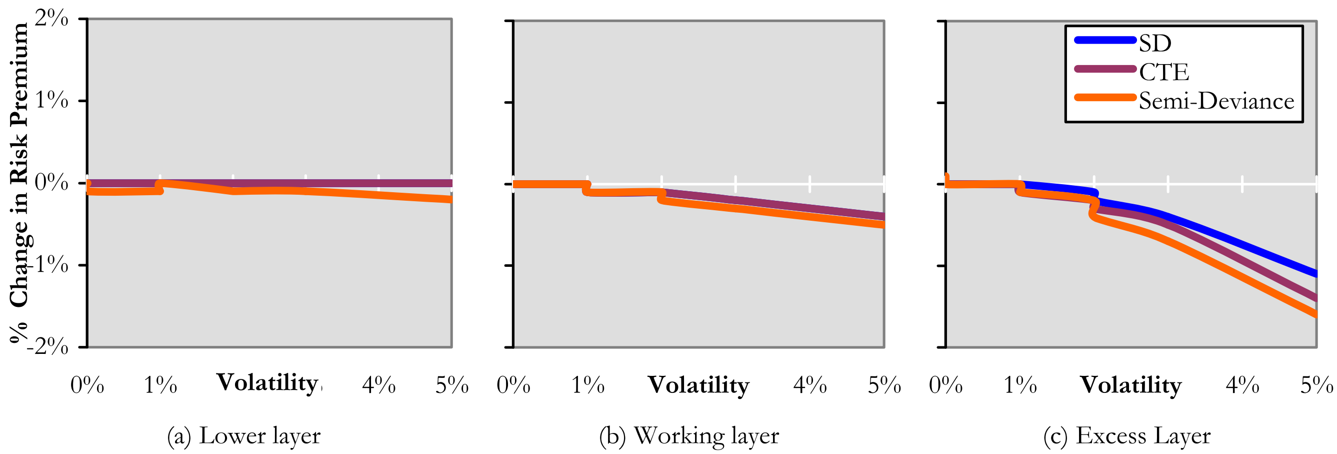


Figure 12. Percentage change in risk premium for increasing levels of inflation volatility (as measured relative to deterministic inflation).[6]

4.7.4 Going forward

The key implication of this section is that as the amount of ground-up inflation increases, insurers playing in higher layers need to worry more about their best estimate liability and less about their risk margin, relatively speaking.

[6] Note that the VaR amount is not shown here because, when dealing with relative amounts so small in magnitude, it is difficult to precisely estimate VaR using simulation techniques.

5. CONCLUSION

The primary intention of this paper was to explore the effect of inflation on several common areas of actuarial modeling. Where possible, we tried to present certain basic rules of thumb which might help provide general guidance to actuaries when working with inflation. However, we note that the exact magnitude and effect of inflation on losses is highly uncertain and will heavily depend on the actuary's unique situation; so we would hope that this paper will be used as proof that inflation should in a real, and non-trivial manner, be incorporated into most actuarial models.

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Abbreviations

ALM, asset liability matching
CAS, Casualty Actuarial Society
CEIOPS, Committee of European Insurance and Occupational Pensions
CTE, conditional tail expectation
CV, coefficient of variation
DLF, decreased limit factor
ERM, enterprise risk management
ESG, economic scenario generator
EVPV, expected value of process variance
ILF, increased limit factor
QIS, qualitative impact study
Semi-SD, semi-deviation
SCR, Solvency Capital Requirement
SD, standard deviation
VaR, value-at-risk
VHM, variance of hypothetical means
VTM, variance-to-mean ratio
XOL, excess-of-loss

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