Insurance Spirals and the Lloyd's Market

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Abstract

This paper presents a model of reinsurance market spirals, and applies it to the situation that existed in the Lloyd's and London reinsurance markets in the second half of the 1980s. It shows that the key contributory factors - a tendency for retrocession business to be placed and remain within the market, low retentions, underwriters' misjudgements regarding their exposure coupled with failures to purchase sufficient reinsurance to protect accounts against known exposures, and an irrational premium structure in the catastrophe reinsurance and retrocession markets - were all present in the London Market at the time.

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INSURANCE SPIRALS AND THE LLOYD'S MARKET

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1 INTRODUCTION

1.1 Background

Between 1987 and 1990 world insurance markets were impacted by a series of major catastrophes, including *inter alia* North European storms (1987), the destruction of the Piper Alpha oil platform and Hurricane Gilbert (1988), the San Francisco earthquake, Hurricane Hugo and the grounding of the Exxon Valdez tanker (1989) and further North European storms (1990). Though not necessarily unforeseeable, a series of losses on this scale was in fact highly unlikely.[2] Insurers in the London Market in general and Lloyd's in particular suffered serious losses[3].

As a major insurance market, specialising in catastrophe insurance, Lloyd's was bound to carry a significant share of the losses. However, Lloyd's insurers' share appears to have been considerably greater than their normal share of catastrophe insurance business[4]. The abnormally high share reflected a heightened exposure to risk that was intimately connected with the "spirals" that existed in the London excess of loss (XL) insurance market at the time - the genesis, nature and implications of which were not well understood by many of the professionals working in the Lloyd's insurance market[5].

The objects of this paper are, first, to model the processes involved in insurance market spirals and analyse the incidence of loss amongst the reinsurers concerned[6];

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[1] I am indebted to Bob Carter, Gerda Dewit, Paul Fenn and Robin Milne for comments on an earlier draft of this article. The usual disclaimers apply.

[2] Mr Harold Clarke of Bacon & Woodrow, a firm of actuaries, calculated that, taking a cut-off of $500m per loss, the likelihoods of experiencing losses greater than those that actually occurred in each of the years 1987, 1988, 1989 and 1990 were 1 in 3, 1 in 20, 1 in 125, and 1 in 47 respectively. **[Phillips (1994)** p 128**]**.

[3] For the period 1989-92 Chatset have estimated that certain Lloyd's syndicates incurred losses of some £3.5 billion from this kind of business . [**Cresswell (1996)**, p.103].

[4] See **Phillips (1994),** p. 12 and **Walker (1992)**, p. 9. Lloyd's is estimated to have carried 55 per cent of the total loss arising from Piper Alpha, and for the North European storms in 1987 and 1990 and for Hurricane Hugo in 1989 the corresponding figures were 31 per cent, 36 per cent and 36 per cent respectively. An independent estimate of Lloyd's likely exposure to losses in the event of a major US storm in 1984 put the corresponding figure at only 15.1 per cent. [**AIRAC (1986)**, table 14, p.23.]

[5] "Not all specialist underwriters were aware in 1987 of the 'spiral'", and "Even the underwriters engaged in LMX (London Market Excess of Loss business) did not fully understand the effect of the spiral." See **Gatehouse (1994)**, p. 18

[6] I am not aware of any model of insurance market spirals in the generally accessible literature. The only attempt to construct a formal model that I have found is in **Institute of Actuaries (1988), 1**, which includes tables and graphs based upon a similar, but simpler, model.

and secondly, by applying the model to the situation that existed at Lloyd's, to show why Lloyd's syndicates were exposed to such serious losses when the catastrophes occurred.

1.2 Risk-bearing and risk dispersal in the insurance industry

Insurance market spirals arise from the interplay of practices employed by the insurance industry to disperse risk and spread it across insurers with the financial resources to carry it. Key elements are:

- the subscription (or co-insurance) method as a means of placing large risks;
- XL reinsurance as a means of laying off risk;
- the practice of purchasing XL reinsurance in "layers";
- and the necessity for underwriters to estimate their "Probable Maximum Loss" (PML)[7] when determining their need for XL reinsurance cover.

An insurer's ability to bear risk is governed by its capital resources - the risks underwritten must not be so large as to absorb more than the insurer's available capital in the event of a claim being made. In practice insurers try to ensure that the claims arising from a single event are unlikely to absorb more than a fraction of the available capital support. This means that large[8] single risks, or the risk of large claims arising from single events, must be distributed across a considerable number of insurers, each bearing only a fraction of the total risk.

The dispersal, or "pulverisation", of risk is achieved by two methods:

- The *subscription* method enables individual primary insurers to subscribe for a proportion of the total risk, with subscribers being sought until cover has been provided for the total risk. Large risks are normally placed in this way.

- Primary insurers commonly subscribe for a larger share of a risk than they can safely retain for their own account, and *reinsurance* provides a means for them to transfer part of the risk that they accept to other insurers, thus increasing the pool of capital available to support the risk. Further capital support may be obtained through *retrocession*, in which the reinsurers themselves lay off (retrocede) part of the risk that they have taken on.

In the case of *catastrophe* risk, for example the risk of a loss accumulation resulting from a single event such as a windstorm[9], reinsurance or retrocession normally takes the form of *excess of loss (XL)* contracts: that is, the reinsurer (retrocessionaire) agrees to meet losses due to claims in excess of a *deductible* retained by the primary insurer or reinsurer. Thus if the catastrophe occurs, the first round of claims is borne

[7] Or some comparable estimate of "extreme" loss, such as the maximum possible loss (MPL) or estimated maximum loss (EML).

[8] "Large" in this context has to be judged by reference to the capital resources of the insurer concerned: large insurance companies can accept risks in their entirety, whereas individual small companies or Lloyd's syndicates would be able to accept only a part.

[9] The term *catastrophe* may also be applied to a very large loss from a single risk, such as the destruction of the Piper Alpha oil platform.

by the primary insurers. These then make claims on their reinsurers to recover amounts - up to the limit of their reinsurance cover - in excess of their deductibles; and the reinsurers in turn make claims[10] on the retrocessionaires for claims in excess of their (the reinsurers') deductibles. The process continues until there are no further reinsurance[11] claims, by which point the losses (i.e. net claims) borne by the insurers and reinsurers involved must in aggregate equal the total insured losses.

Excess of loss reinsurance is typically placed in *layers*, that is one reinsurer will provide cover for a layer of claims in excess of the primary insurer's deductible, a second for a layer of cover if claims should exceed the threshold provided by the primary insurer's deductible plus the first layer of cover, and so on. This practice helps to disperse the risk inherent in large losses by bringing in more insurers, and it also contributes to specialisation in risk-bearing because the returns earned from writing the higher layers of reinsurance are more volatile than those from writing lower layers: while in most years there will be no claims that "invade" the higher layers, when claims do occur they are likely to be large in relation to the premiums paid in that year.[12] The reinsurance premiums normally decline for successively higher layers of cover, because the probability of a claim invading any given layer reflects the (normally diminishing) probability that the insured losses will exceed the relevant threshold and because claims administration costs associated with the higher layers of cover are relatively small[13].

In order to determine how much reinsurance cover they require, underwriters have to make an estimate of the *PML* of their insurance portfolio. In the case of a single installation, such as an oil platform, insured losses equal to the insurance cover granted may be contemplated - in which case the PML would equal the total cover- though insurers may take the view that the risk of a *total* loss for a single property can be discounted and that the PML can therefore be set at a lower level. For a catastrophe such as a windstorm or earthquake, where there is a potential agglomeration of losses, the PML is likely to be less than 100% of the aggregate cover under the relevant policies. In a diversified insurance portfolio, in which the degree of correlation between the individual risks has been controlled, the PML will reflect that diversification and be much less than the aggregate of the insured risks[14].

In conjunction with the amount of risk that the underwriter wants to retain, the PML determines the underwriter's perceived need for reinsurance cover. To guard against

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[10] Up to the limit of *their* cover.
[11] Henceforth the term reinsurance includes retrocession.
[12] For similar reasons, the provision of retrocession cover is riskier than the provision of reinsurance for the same insured event.
[13] In economic terms the *fair* premium for any given layer reflects the expected value of claims and associated administration costs plus a return on the capital at risk. The volatility of the outcome should affect the return on capital only to the extent that the risk is non-diversifiable, but in practice inelasticity of supply of (high) risk-bearing capacity has meant that premiums paid for the higher and more volatile layers of cover allowed for an above-normal expected return on capital. These abnormal expected returns are likely to be eroded by the development of catastrophe insurance bonds, which increase the supply of risk-bearing capital.
[14] A key skill of the insurance underwriter is to judge the PML of a portfolio of insurance policies, and indeed to structure insurance portfolios so that, through diversification, the degree of correlation between the risks is controlled.

the risk of agglomeration losses an underwriter seeks *single event* XL cover, that is cover against the risk that the total claims from a particular class of business (e.g. marine or household insurance) as a result of a single event exceed an agreed level (the deductible), and/or *whole account* XL cover, that provides similar protection against all types of insured losses (e.g. property, motor etc.) Reinsurers in turn may seek (*XL on XL*) cover from retrocessionaires. Again, this reinsurance cover is normally purchased in layers.

The protection provided by such cover is not unlimited - it enables insurers to recover losses in excess of their deductibles *only up to the limit of their reinsurance.* Moreover, while losses beyond the PML should be improbable they are seldom inconceivable. Thus there is generally a possibility of *PML failure*, with insured losses exceeding the estimated PML and the insurer having to carry the excess losses.

1.3 The incidence of losses and the level of claims

In normal circumstances losses arising from single events are borne by primary insurers, reinsurers and retrocessionaires in accordance with their deductibles, the higher layers of cover being invaded only if the losses are sufficiently large.[15] However, in the case of insurance portfolios for which the PMLs are less than the theoretical maximum aggregate cover granted, insurers at all stages in the process run the risk of experiencing losses in excess of their deductibles. This will occur whenever the total claims on them exceed their deductibles plus reinsurance cover. If some insurers suffer PML failure before others have exhausted their cover, the distribution of losses across insurers will not reflect their intended exposure.

One consequence of the practice of dispersing risk through reinsurance is that the total gross value of claims exceeds the total insured losses whenever losses are sufficiently large to trigger reinsurance claims. Suppose that a risk is placed by the subscription method amongst a number of insurers, that each primary insurer retains 50% of the cover granted as a deductible and reinsures the other 50% on an excess of loss basis, that each reinsurer does likewise, and that retrocessionaires retain 100% of the risk that they accept. A loss event resulting in insured losses of up to 50% of the cover granted will be retained entirely by the primary insurers: gross claims equal total insured losses. In the case of a loss event resulting in insured losses equal to between 50% and 75% of the cover granted, the excess over 50% will result in claims on the reinsurers. Thus the loss event gives rise to gross claims that exceed the insured losses by the amount of these reinsurance claims. For losses between 75% and 100% of the cover granted, reinsurers will seek to recover losses in excess of 75% from the retrocessionaires, adding a further round of claims. The result is that an insured loss amounting to 100% of the available cover would give rise to gross claims equal to 175% of the losses[16]. In general, even in the absence of a spiral, the relationship

[15] Assuming that there is no "spiral" exposure (see below) and that reinsurance cover up to the maximum insured loss is in place.

[16] Insured losses of 100 would give rise to gross claims on primary insurers of 100, on reinsurers of 50, and on retrocessionaires of 25, with corresponding net claims (i.e. retained losses) of 50, 25 and 25 respectively. Note that this example assumes that no insurer is involved at more than one stage of the process.

between the total gross claims generated by a loss event and the level of insured losses depends on the structure of the primary, reinsurance and retrocession contracts involved.

2 CHARACTERISTICS OF INSURANCE SPIRALS

In a normal situation when an insurer (or reinsurer) makes a claim on a reinsurance policy it has purchased the recovery does not lead to any further claims on that insurer. In an insurance market spiral, however, claims made by reinsurers[17] at one level result in the same reinsurers receiving additional claims under reinsurance policies that they have written. Since the reinsurers in question have already received claims in excess of their deductibles from the particular loss event, provided that they have sufficient reinsurance cover in place the additional claims they receive then trigger further claims by them on higher layers of reinsurance cover. This situation is likely to occur when reinsurers seek to protect their own positions by purchasing XL reinsurance cover, and at the same time write XL reinsurance policies for other reinsurers who are liable to be affected by the same loss events.

In practice spirals are most likely to occur when reinsurers provide cover for each other on similar lines of business, when the bulk of the relevant reinsurance is XL business and when retrocession business includes cover for claims arising from XL business (i.e. it is XL on XL business). In these conditions the reinsurance claims generated from insured losses in excess of the primary insurers' and reinsurers' deductibles are passed on in full,[18] and continue to recirculate until some reinsurers run out of cover. These conditions applied to syndicates at Lloyd's and many other members of the London Market in the second half of the 1980s: they participated in both direct and reinsurance business, and provided mutual reinsurance and retrocession cover for each other, with the result that claims arising from the same loss event were passed to and fro within the group[19].

Insurance spirals thus serve to concentrate, rather than disperse, risk. Contrast the following situations. In the first, European reinsurers retrocede part of their European (XL) windstorm risk to Japanese reinsurers, while the latter retrocede part of their Japanese (XL) windstorm risk to European reinsurers. Because the risks of windstorms in Europe and Japan are independent, the retrocession[20] helps to disperse risk. In the second case, suppose that the Japanese reinsurers retrocede part of the European windstorm risk back to the European reinsurers. In this case the retrocession helps to concentrate risk, because if there is a European windstorm the claims experienced by the European reinsurers will reflect not only the original claims of the primary insurers on them, but also the claims that they made on the Japanese reinsurers, part of which will return to them.

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[17] Or direct insurers who also write reinsurance business.
[18] Theoretically, a spiral could occur even if all reinsurance was proportional, though in that case the fact that a significant proportion of the risk was retained at each round would limit its extent.
[19] When primary insurance and reinsurance are handled by separate departments, avoiding duplication of this kind depends on having a very effective system of management controls.
[20] Which is XL on XL business.

Insurance spirals are characterised by PML failure. Once the insurers' and reinsurers' deductibles have been exhausted, any further losses remain in the spiral until the top layer of some reinsurer's own reinsurance cover runs out. At that point any such reinsurer must, involuntarily, retain the loss. This adds to the concentration of risk, because within any insurance market losses through PML failure tend to be concentrated on those reinsurers whose reinsurance cover runs out first, rather than being dispersed widely throughout that market.

In an insurance spiral the direct connection between the level of insured losses and the triggering of claims on any given layer of reinsurance is broken. The total of claims is inflated by the recirculation of claims amongst insurers.[21] Because the reinsurance is generally purchased in layers, whenever an insurer's retentions have been exceeded but its reinsurance cover has not been exhausted, the further reinsurance claims arising from a single loss event are passed on *in full*, so that even a relatively minor catastrophe may trigger claims under relatively high layers of reinsurance cover.[22]

Thus a further consequence of an insurance market spiral is that the normal relationship between the layer of reinsurance cover and the probability of a claim being made is subverted. If claims are passed from lower to higher layers of reinsurance cover in full, instead of premiums being materially lower for high than for low layers of cover they should, in principle, remain constant.[23] Moreover, when the link between the size of the original loss and the probability of a claim being made on any layer of reinsurance is broken, it is impossible to make an objective estimate of the probability of a claim without detailed knowledge of the structure of the intervening reinsurance

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[21] Claims arising from the Piper Alpha disaster are said to have amounted to some 10 times the insured losses. [**Walker (1992)**, paragraph 2.14]

[22] An example of how this process operates is contained in **Gooda Walker (1992**) (p. 11):

"Insurer A writes a direct account and decides he needs reinsurance protection of $9m in excess of $1m. He buys this reinsurance protection 100% from insurer B in nine layers of $1m in each. Insurer B also writes a direct account and decides that he needs reinsurance protection in the sum of $9m in excess of $1m. He buys this 100% from insurer A in nine layers of $1m each. The situation at this moment is that A and B are each other's reinsurers. Let us suppose that A now writes one direct risk with an exposure of $3m.

Insurer A is now notified of a claim for $3m from the direct risk written which he subsequently pays. He must suffer the $1m net (the deductible under his reinsurance programme) but can claim the excess $2m from reinsurer B. Having paid $2m to A, reinsurer B retains a net loss of $1m (the deductible under B's reinsurance programme) and claims the excess $1m as a reinsurance claim on A. Reinsurer A has already dealt with a claim on this original loss totalling $3m and treats the further claim as part of the same original loss. He pays the claim and then makes a reinsurance recovery of $1m from B. Cumulative gross payments by A at this point are $4m from the original loss of $3m. Reinsurer B pays the claim of $1m to A who in turn pays a claim of another $1m to B. This process continues with A retaining $1m at the bottom of his programme and B retaining $1m at the bottom of his programme. In total, A and B claim $9m and $8m respectively from each other as the claim moves through the spiral. Ultimately insurer A is left with a $1m claim from B which he cannot recover through reinsurance because A runs out of reinsurance first. At the end of the process therefore the original loss of $3m has fallen $2m net to A and $1m net to B. Cumulative gross claims payments total $11m for A and $9m for
B. [Volume 1, chapter 2, paragraphs 7.2.1 and 7.2.2]

[23]If claims are not passed on in full, premiums should fall to the extent that claims passing through to higher rounds are eroded by deductibles.

contracts. In reality, acquiring the necessary detailed knowledge is unlikely to be practicable for retrocession business [24], particularly when the subscription method of placing business multiplies the number of contracts and reduces the transparency of the underlying insurance contracts.

Finally, the *capacity* of an insurance market for risk can be measured by the sum of the deductibles of the insurers and reinsurers in the market with regard to that risk. Beyond their deductibles the insurers and reinsurers purchase reinsurance cover up to their PMLs. Thus, if a loss occurs that is greater than the sum of all the insurers' and reinsurers' deductibles, PML failure is unavoidable - *some* insurers' or reinsurers' PMLs must prove to be too low. When a spiral exists, even PMLs that are a substantial multiple of the maximum credible original loss may prove to be inadequate.[25] It is in the nature of a PML that it is an *estimate* of the maximum loss that can reasonably be expected to arise from the insurer's portfolio, and in the absence of the information necessary to calculate the PMLs with any precision in these conditions, it will hardly be surprising if some insurers get it wrong. Indeed, if insurers accept risks for which the market does not have sufficient capacity on the basis that they can lay off the surplus risk through reinsurance, in the event of a sufficiently large insured loss PML failure for some market participants is inevitable.

3 MODELLING THE SPIRAL

3.1 A General Model

Assume that there is a group of m "inside" reinsurers within a market, who reinsure business with each other. Assume further that they place some of their reinsurance outside the market, and that none of that reinsurance is retroceded back into the market i.e. it is all retained outside the market. For simplicity insurers outside the market can be treated as a single, (m+1) th, "outside" reinsurer.   Let the i'th inside reinsurer have a retention D_i, $i = 1....m$, and let it purchase reinsurance R_i. Let R_{ij} be the reinsurance cover purchased by the i'th reinsurer from the j'th reinsurer ($i = 1....(m+1)$)[26]. Since no reinsurer purchases cover from itself, it follows that:

$$R_i = \sum_{j=1}^{m+1} R_{ij} \qquad\qquad R_{ii} = 0$$

The cover provided by the j'th inside reinsurer is:

$$\sum_{i=1}^{m} R_{ij}$$

[24] Consequently, as a matter of policy some major reinsurance companies generally did not accept XL on XL business [**Phillips (1994)** p. 31]

[25] Of course, PML failure may also be due to insurers underestimating the maximum amount of the original losses, and unintended losses may also be experienced as a result of insurers failing to purchase sufficient reinsurance to protect losses of up to their PMLs.

[26] For simplicity, the effect of layering is ignored, i.e. the reinsurers are assumed to subscribe the same proportion of all the layers of any reinsurance programme.

and the cover provided by the outside reinsurer is:

$$\sum_{i=1}^{m} R_{i,(m+1)}$$

Now suppose that the inside reinsurers receive claims of ($X_i + D_i$) in respect of a loss event, where $0 < X_i < R_i$ for all i.

The i'th inside reinsurer seeks to recover X_i from its reinsurers and accordingly claims

$$X_i\,[R_{ij} / R_i],\ \ j = 1, \ldots ,(m+1)$$

from the j'th reinsurer. The total such claims received by the j'th reinsurer are therefore:

$$\sum_{i=1}^{m} X_i\,[\,R_{ij} / R_i],\ \ \ j = 1, \ldots ,(m+1)$$

At this point the j'th inside reinsurer has received gross claims in respect of the loss event amounting to:

$$X_j + D_j\ +\ \sum_{i=1}^{m} X_i\,[\,R_{ij} / R_i\,],\ \text{ and provided that}$$

$$X_j +\ \sum_{i=1}^{m} X_i\ \ [R_{ij} / R_i\,] <\ R_j$$

it is entitled to recover a further

$$\sum_{i=1}^{m}\ \ X_i\ \ [R_{ij} / R_i\,],$$

from its reinsurers. Of this amount, only the claims falling on the outside reinsurer,

namely $\sum_{i=1}^{m} X_i\,[R_{i,(m+1)} / R_i\,]$

are not recirculated. As a result, at the next round, reinsurer i receives claims amounting to:

$$\sum_{j=1}^{m} [R_{ji} / R_j] \sum_{i=1}^{m} X_i\,[R_{ij} / R_i\,]$$

with $\sum_{j=1}^{m} [R_{j,(m+1)} / R_j] \sum_{i=1}^{m} X_i\,[\,R_{ij} /\ R_i\,]$

falling on the outside reinsurer.

This process continues until one of the following occurs.

1 The total claims on the outside reinsurer amount to

$\sum_{i=1}^{m} X_i$ - i.e. to the total insured losses covered by the inside reinsurers less their deductibles - before any inside reinsurer has exhausted its reinsurance cover, R_i. In this case, the cumulative claims on the i'th inside reinsurer cannot exceed $R_i + D_i$, for all i.

2 The reinsurance cover of one or more inside reinsurers is exhausted before the reinsured part of the losses has been passed in full to the outside reinsurer. From this point on the inside reinsurer in question is in the same position as the outside reinsurer, having to retain any further claims falling on it. Total retentions at each subsequent round are then divided between the relevant inside reinsurers and the outside reinsurers in proportion to the claims falling on them.

3 The reinsurance cover of <u>all</u> the inside reinsurers is exhausted. At this point the part of the initial loss that has not already been retained is divided between the inside reinsurers in proportion to the final round of claims on them.

It follows that the existence of mutual reinsurance within an insurance market does not *necessarily* lead to unintended losses: so long as there are outside reinsurers willing and able to participate in the reinsurance, and the insiders arrange sufficient reinsurance cover, losses in excess of the insiders' deductibles will in the end be borne by the outsiders. However, because the spiral inflates the level of gross claims, the level of reinsurance required to achieve this may be very high; and if outside insurers are less willing to provide high layers of cover than insiders, the end-result is that insiders will be left to carry the residual losses.

3.2 A Simplified Model

While the general model demonstrates the complexity to which interdependent, mutual reinsurance arrangements give rise, it is too general to provide useful results. To simplify matters let us assume therefore that there are three groups of insurers, outsiders and two groups of insiders, who behave as follows: the outsiders accept risk, but do not reinsure (at least with insiders); the first group of insiders reinsure up to a certain level, but are prepared to accept higher layers of reinsurance from other insurers; and the second group of insiders write and reinsure up to the same level. Specifically, let us assume that there are a large number, n, of reinsurers, all of equal size[27], that the fraction α are outside the relevant group, and that the insiders fall into two groups comprising the fractions β_1 and β_2 of the insiders, (i.e. $\beta_1 + \beta_2 = 1$). Assume that insiders have reinsurance cover in place of R_1 and R_2 ($R_2 > R_1$) respectively, but that both groups subscribe to all layers of reinsurance cover up to R_2. Assume also that each outside reinsurer subscribes to layers of cover up to a maximum of R_0, and that $R_0 < R_1$, i.e. that the outside reinsurers participate only in the

[27] This involves no loss of generality, as large reinsurers can be considered as consisting of the appropriate number of the standard size of reinsurer. If this standard size is assumed to be small, then the numbers of both inside and outside reinsurers can be treated as large, and the fact that reinsurers do not place any reinsurance directly with themselves can be ignored.

lower layers of reinsurance programmes. Finally, without loss of generality, assume that the insiders' deductibles, D_1 and D_2 respectively, are both zero, so that the original loss, X, experienced by each inside reinsurer is fed through in full into its first round claim on other reinsurers.

Case 1

Suppose that the cover provided by the outside reinsurers has not been exhausted. Of the first round claim the proportion $(1 - \alpha)$ falls on inside reinsurers and α falls on outside reinsurers. The second round claim made by each inside reinsurer will then be $(1 -\alpha)X$, and the spiral will continue with claims at the k'th round of $(1 - \alpha)^{k-1}X$. After k rounds the total claims by each inside reinsurer will therefore be

$$X\,[1 + (1 - \alpha) + \ldots\ldots + (1 - \alpha)^{k-1}]$$

$$= \quad [X/\alpha]\,[1 - (1 - \alpha)^k]$$

The limit of the cover provided by the outsiders is R_0, so the process can continue so long as

$$[X/\alpha]\,[1 - (1 - \alpha)^k] \ < \ R_0$$

or $$(1 - \alpha)^k > 1 - \alpha R_0/X$$

Since the outsiders subscribe the fraction α of each layer of cover for the insiders, the cover provided by outsiders for each insider is αR_0. If the insider's original loss, X, is less than αR_0, the right-hand side of this expression is negative, and there is no theoretical upper limit on k. Thus within this range of loss the spiral of claims (becoming smaller at each round) can continue indefinitely, and in the end *the entire loss will be met by the outside reinsurers*[28].

Case 2

If the original loss is greater than the cover provided by outsiders, i.e. $X > \alpha R_0$, then the right hand side of the expression is positive. It follows that there is an upper limit to k, reached when the level of claims by each inside reinsurer equals R_0, at which point the reinsurance cover provided by outsiders will be exhausted.

Each inside reinsurer has by then recovered (net) αR_0 of its original loss, X, so that the next round of claims (now falling only on the inside reinsurers) amounts to

$$X - \alpha R_0 \ = \ Z$$

[28] The total of the claims generated by each inside reinsurer, including the original claim of X , is $X[1 + 1/\alpha]$, up to a maximum of $\alpha R_0[1 + 1/\alpha] = R_0[1 + \alpha]$

Since there are no more retentions until some inside reinsurers run out of cover, claims at this level are passed on in full and ascend the spiral amongst the inside reinsurers until the total claims by each inside reinsurer have reached R_1 , at which point the first group of inside reinsurers exhaust their reinsurance cover and are unable to pass on any outstanding or further claims.[29]

However, the two groups of inside reinsurers are now in different positions. The first group have run out of reinsurance cover, and have to retain (involuntarily) any outstanding claims or further claims on them. The second group continue to be able to pass on claims until they reach the limit of *their* reinsurance cover, namely R_2.
In effect, as regards further participation in the spiral, the first group have become outsiders, whilst the second group remain as insiders.

The cover purchased by each of the second group from the first group is $\beta_1[R_2 - R_1]$. Thus within the range of original loss given by

$$\alpha R_0 < X < \alpha R_0 + \beta_1[R_2 - R_1]$$

or $$0 < Z < \beta_1[R_2 - R_1]$$

the first group have to retain not only their own net losses when they run out of reinsurance cover, Z, but also the further reinsurance claims from the second group. For each member of the first group these additional claims amount to $[\beta_2/\beta_1]\, Z$,[30] giving total losses of $Z\, [1 + \beta_2/\beta_1]$.

Case 3

The second group of inside reinsurers runs out of reinsurance cover when

$$Z = \beta_1[R_2 - R_1] ,$$

at which point the involuntary losses borne by each of the first group amount to

$$[R_2 - R_1] .$$

If the original loss exceeds this threshold the balance is retained by the reinsurer.

Thus for

$$X > [\alpha R_0 + \beta_1(R_2 - R_1)]$$

the losses borne by each of the first group are

$$[R_2 - R_1] + \{X - [\alpha R_0 + \beta_1(R_2 - R_1)]\}$$

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[29] At this point the total claims generated by each inside reinsurer amount to

$$R_0[1 + \alpha] + [R_1 - R_0] = [R_1 + \alpha R_0]$$

[5] Within this range the additional claims generated by each of the second group of inside reinsurers amount to Z/β_1 , up to a maximum of $[R_2 - R_1]$

and by the second group are

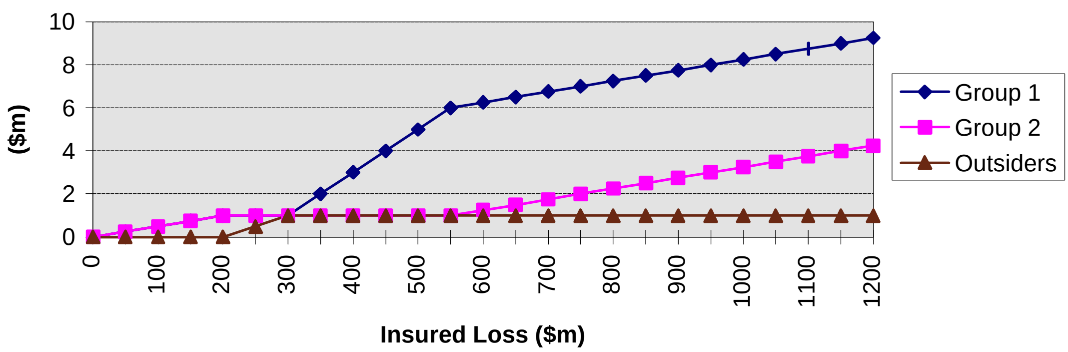
$$\{X - [\alpha R_0 + \beta_1(R_2 - R_1)]\}$$

3.3 Illustrative Example

The incidence of losses across all the reinsurers is illustrated in the following example. Suppose that insurance cover is provided for damage to (including the complete destruction of) an oil rig, with a maximum potential liability of $1200m. Suppose that it is provided by 200 insurers (the insiders), each of unit size, who provide $6m of cover each. Suppose further that each inside insurer retains the first $1m of loss and buys XL reinsurance (in layers) to cover the other $5m of potential loss. The first three layers of $0.5m reinsurance are spread equally amongst each of the inside insurers and 100 outside reinsurers (i.e. R_0 = $1.5m), while the next $3.5m are provided equally by all the insiders (R_1 = $5m). Finally, suppose that 50 of the insiders (group 1) do not purchase any further reinsurance, but that the other 150 (group 2) purchase additional reinsurance cover up to $10m ($R_2$ = $10m), this being provided equally by all the insiders.

Chart 1 shows the loss retained by each insurer if an insured loss of $Xm is incurred.

Chart 1: Incidence of Loss



Insured losses of up to $200m are covered by the deductibles of the inside insurers and are absorbed (voluntarily) by them. The next $100m of insured losses fall entirely on the outsiders: within this range insiders are able eventually to recover from the outsiders any losses in excess of their deductibles. Losses in the range $300-550m fall entirely on the first group of inside reinsurers - as a result of the spiral any insured loss in excess of $1.5m for each insider (i.e. $300m in total) leads to reinsurance claims of more than $5m and so exhausts the first group's cover. These *involuntary* losses have to be added to their deductibles of $1m. Any insured loss beyond $550m (i.e. original claims of $2.75m) falls on both groups of insiders because at this point their $10m of reinsurance cover has been exhausted. All therefore experience further *involuntary* losses.

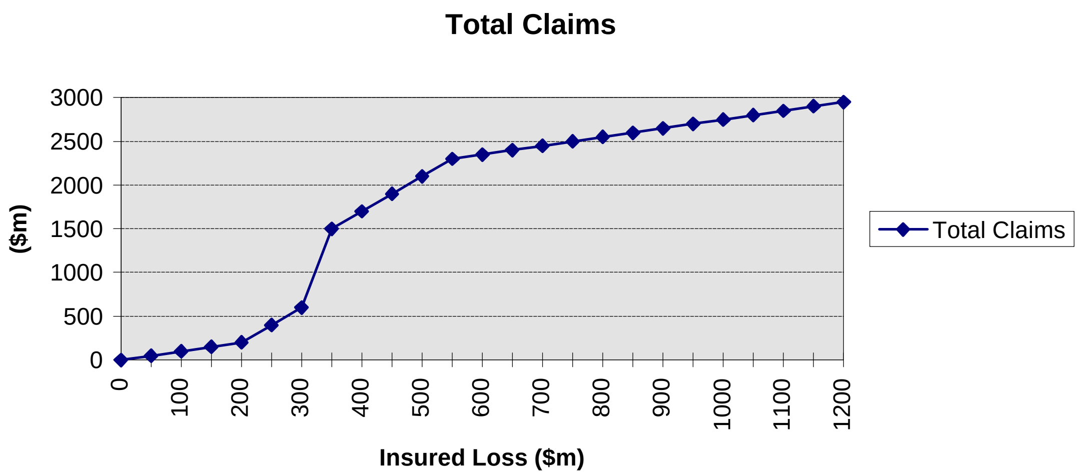


Chart 2 illustrates how the total level of claims is magnified in the course of the spiral. Since the first $200m of claims from an insured loss are retained by the insurers any loss up to that amount does not give rise to reinsurance claims: total claims are therefore equal to the insured loss. Thereafter the total claims rise rapidly. For an insured loss of between $200m and $300m, only 1/3 of any reinsurance claims are retained by outsiders, with the balance leading to further claims - in this range the addition to claims is 4 times the additional insured loss, so that an insured loss of $300m generates total claims of $600m. At this point total claims rise precipitously - by another $700m - before any further losses are retained (e.g. insured losses of $301m would generate total claims of just over $1300m). Further losses in the range $300 - 550m generate claims amounting to 4 times the additional losses, taking the total of claims to $2300m. Since insured losses of $550m exhaust the reinsurance cover of all the insurers, higher levels of insured loss do not generate any further reinsurance claims, so that gross claims rise only in line with the insured loss.

3.4 Other participants in spiral business

The simplified model and illustration above actually understate the possible extent of spiral business because they omit one important category of reinsurer. So far the insurers considered in the models have behaved in one of the three ways set out at the beginning of section 3.2. However, there is also a fourth group to consider - inside reinsurers who accept layers of reinsurance up to one level but purchase sufficient reinsurance at higher levels to ensure that their own exposure to unintended losses does not increase. Business written by such reinsurers adds to the total level of claims in the spiral[31].

It is worthwhile asking how it can be profitable for an underwriter to write such business, when in practice taking little, or even no, risk. There are two sets of conditions in which it may occur.

[31] Reinsurers in this fourth category provide capacity only to the extent that they retain some of the risk themselves, i.e. to the extent that the reinsurance purchased is less than the reinsurance accepted. Thus the volume of claims in the spiral is inflated by the amount of the reinsurance purchased.

First, an underwriter's own whole account XL reinsurance arrangements may be put in place before the business for the period in question is written. If there is excess capacity in the market and it is difficult to win business the underwriter may be in a position to write more business without exceeding the PML on which his reinsurance arrangements have been based. In this situation additional business, even at marginal rates, makes a contribution to profits without unintended exposure to risk.

The second set of conditions depends on an irrational pricing structure for successive layers of XL reinsurance cover. In normal circumstances the risk of catastrophe losses of a given amount diminishes as the size of the losses increases, with the premiums charged reflecting the diminishing probability of loss[32]. The existence of a spiral modifies the normal relationship as regards the probability of loss, but is not necessarily associated with a corresponding change in the premium structure.

The effect of a spiral on the probability of loss is complex, as can be illustrated by reference to Chart 2 above. For relatively small losses that fall within the insurers' own retentions the spiral does not operate, and no modification is required. For the lowest layers of reinsurance (i.e. up to R_0), where the losses will ultimately be borne by outsiders, the probability of a claim of a given size is magnified by the spiral. In this range the probability of any given layer being invaded by a claim continues to diminish with the height of the layer, but in comparison with a non-spiral situation it does so at a reduced rate, the degree of the reduction depending on the extent to which claims fall on outside rather than inside reinsurers. For the layers between R_0 and R_1, the probability of a claim does not diminish at all, because any claim that invades the lowest of these layers passes through in full into the layer above R_1. Finally, in the layers between R_1 and R_2, the probability of a claim again diminishes, because the first group of insiders retain unintended losses, though at a rate that reflects the fact that a proportion of the claims (those on the second-group) are recycled into higher layers.

Rational pricing of successive layers of reinsurance would therefore have to take account, not only of the probability of loss events of particular sizes occurring, but also of the structure of claims within the reinsurance market. When a spiral structure exists in the market, the probability of a claim invading any given layer is much higher than when there is no spiral, and in the absence of significant retentions from the claims on each layer, the diminution of risk from one layer to the next is minimal. In practice there is unlikely to be enough information available to reinsurers in such conditions to enable them to price business rationally[33].

If the existence and implications of spiral business are not fully recognised in the market, the conventional premium structure may be maintained, with the higher layers of cover being placed at rates that are unjustifiably low in relation to the risks involved. It is then possible for some underwriters to participate in spiral business profitably and

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[32] On the assumption that the greater volatility associated with the higher layers of cover warrants a higher expected return, premiums should theoretically fall by less than in proportion to the expected value of the loss.

[33] See **Institute of Actuaries (1988), 2**: "....it is now almost impossible to analyse the contents of the book of business written by an underwriter in a subscription market; it is therefore not possible to quantify exposure...." (p. 125).

risklessly by placing high layers of reinsurance at premiums lower than they can obtain for the lower layers they themselves accept.[34]

4 THE LLOYD'S INSURANCE SPIRALS

It is not difficult to point to a number of features of the Lloyd's and London Markets that contributed to the development of reinsurance spirals in the second half of the 1980s.

First, there was very little participation in the market for XL retrocession business outside of the London Market[35]: in terms of the model of section 3.2, α was small. The scope for London underwriters to pass on risk to other markets was correspondingly limited, and risks accepted by the London Market tended to be retained within the market..

Secondly, many underwriters at Lloyd's "retained a very low retention and bought reinsurance to improve their premium to risk position"[36]: In terms of the model of section 3.1, D was frequently very small. As a result, even moderate losses were likely to exceed underwriters' voluntary retentions and set off a spiral of reinsurance claims that penetrated the higher layers of reinsurance programmes.

Thirdly, some underwriters miscalculated their PMLs because "even underwriters engaged in LMX did not fully understand the effect of the spiral"[37], or because they regarded "the higher layers of cover... as virtually risk-free"[38]. Their willingness to accept risks without adequate reinsurance provided the retrocession cover required by other participants in the spiral. Their position is comparable to that of the second group of inside reinsurers in section 3.2 above.

Fourthly, some underwriters accepted business that led to an increase in their PMLs without having sufficient reinsurance cover in place, because of "unexpected demand for cover at attractive rates"[39], "demands for reciprocity"[40], and financial constraints on the amount of premium income spent on reinsurance[41] . Their position may be compared to that of the first group of reinsurers in section 3.2 above

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[34] Such "irrational" pricing structures appear to have existed in the London Market in the reinsurance spirals of the late 1980s.

[35] "The only market for a reinsurance of an LMX underwriter is to all intents and purposes the LMX market itself. The amounts placed overseas are insignificant and are in any case often reinsured on a similar basis back in London." [Paper by Mr Outhwaite, quoted in **Phillips (1994)**, p 60}

[36] **Walker (1992),** paragraph 2.15.

[37] Response of Mr Crane quoted in **Gatehouse (1994)**, p.18

[38] **Phillips (1994)**, p. 86.

[39] Attributed to Mr Gofton-Salmond in **Phillips (1995),** p.88

[40] It has been suggested that, in order to place their own reinsurance cover in the market , underwriters had to be prepared to accept similar reinsurance business placed by others. See for example **Walker (1992)**, paragraph 3.24, "The committee believe that active underwriters on several of the loss-making LMX syndicates were heavily influenced by LMX brokers."

[41] **Phillips (1995)**, pp 54-55

Fifthly, the premium structure for successive layers of spiral business did not reflect the true risk of loss - “the upper layers ... were grossly underrated”.[42] This provided scope for underwriters who fully understood the spiral to participate profitably in spiral business by taking advantage of the disparity between rates for low level and high level layers of business[43], as suggested in section 3.4 above. Moreover, other reinsurers were able to retrocede risk into the London Market at attractive rates, thus increasing London’s share of world-wide exposure to catastrophe losses.

These features may all be regarded as *proximate* causes of the Lloyd’s insurance spirals. The consequence was a very substantial increase in XL reinsurance and retrocession business, including inter-syndicate reinsurance, within Lloyd’s. Gross premium income of “LMX” syndicates[44] identified by the Walker Committee rose from 13.1% of Lloyd’s total gross premium income in 1983 to 26.4% in 1990, and by the late 1980s many other syndicates also had some involvement in XL retrocession business. As regards spiral business within Lloyd’s itself[45], gross inter-syndicate reinsurance premiums as a proportion of Lloyd’s total gross premiums rose from 9.1% in 1984 to 16.1% in 1990.[46] The end-result, when the catastrophes occurred, was losses on a scale that threatened the continued existence of Lloyd’s.

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[42] **Phillips (1995)**, p. 108
[43] **Phillips (1994)**, p.68
[44] Syndicates treated by the Walker Committee as writing significant amounts of LMX (XL retrocession) business.
[45] The spirals also included business amongst Lloyd’s syndicates and other insurers in the London Market, and, to a lesser extent, insurers elsewhere.
[46] Quoted in **Cresswell (1996)**, pp. 77-8.

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