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Insurance Spirals and the London Market*

by A.D. Bain**

1. Introduction

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.[1] Insurers in the London Market in general and Lloyd's in particular suffered serious losses.[2]

As a major insurance market, specializing in catastrophe insurance, the London Market was bound to carry a significant share of the losses. There are no reliable estimates of the losses incurred in the London Market as a whole, but Lloyd's insurers' share appears to have been considerably greater than their normal share of worldwide 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 market.[4]

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;[5] and second, by

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[1] Mr Harold Clarke of Bacon & Woodrow, a firm of actuaries, calculated that, taking a cut-off of $500 million 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).

[2] 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).

[3] 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; 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).

[4] "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).

[5] 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), which includes tables and graphs based upon a similar, but simpler, model.

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applying the model to the situation that existed in the London Market, to show why Lloyd's syndicates were exposed to such serious losses when the catastrophes occurred.

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")[6] 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[7] single risks, or the risk of large claims arising from specific 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 specific event such as a windstorm,[8] most reinsurance or retrocession takes the form of *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 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[9] on the retrocessionaires for claims in excess of their (the reinsurers') deductibles. The process continues until there are no further

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

[7] "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.

[8] 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.

[9] Up to the limit of *their* cover.

reinsurance[10] claims, by which point the losses (that is, 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 set of reinsurers 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 specialization 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.[11] 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.[12]

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 per cent 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.[13]

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 the risk of agglomeration losses an underwriter seeks *specific event* XL cover, that is cover against the risk that the total claims from a particular class of business (for example, 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 (such as property or motor). 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

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[10] Henceforth the term reinsurance includes retrocession.

[11] For similar reasons, the provision of retrocession cover is riskier than the provision of reinsurance for the same insured event.

[12] 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 and other capital market instruments, which increase the supply of risk-bearing capital.

[13] 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.

generally a possibility of *PML failure*, with insured losses exceeding the estimated PML and the insurer having to carry the excess losses.

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.[14] 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 gross value of total claims exceeds the total insured losses whenever losses trigger reinsurance claims. Suppose that a risk is placed by the subscription method amongst a number of insurers, that each primary insurer retains 50 per cent of the cover granted as a deductible and reinsures the other 50 per cent on an excess of loss basis, that each reinsurer does likewise, and that retrocessionaires retain 100 per cent of the risk that they accept. A loss event resulting in insured losses of up to 50 per cent 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 per cent and 75 per cent of the cover granted, the excess over 50 per cent 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 per cent and 100 per cent of the cover granted, reinsurers will seek to recover losses in excess of 75 per cent from the retrocessionaires, adding a further round of claims. The result is that an insured loss amounting to 100 per cent of the available cover would give rise to gross claims equal to 175 per cent of the losses.[15] In general, even in the absence of a spiral, the relationship 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[16] 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

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

[15] 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 (that is, 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.

[16] Or direct insurers who also write reinsurance business.

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 writing 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 (that is, it is XL on XL business).[17] In these conditions the reinsurance claims generated from insured losses in excess of the primary insurers' and reinsurers' deductibles are passed on in full, 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 and in 1990: 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.[18]

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[19] 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.

Insurance spirals are characterized 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,[20] 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 PMLs are breached 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

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[17] 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.

[18] 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.

[19] Which is XL on XL business.

[20] Reinsurers may as a matter of policy leave some of their PMLs unprotected at the top, in which case that element of loss should not be regarded as involuntary – though there is no evidence to suggest that the spiral losses generally came within this category.

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

are passed on *in full*,[22] so that even a relatively minor catastrophe may trigger claims under relatively high layers of reinsurance cover.[23]

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.[24] 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 contracts. In reality, acquiring the necessary detailed knowledge is unlikely to be practicable for retrocession business,[25] 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 maximum deductibles[26] that the insurers and reinsurers in the market would be prepared to accept with regard to that risk. Beyond their deductibles the insurers and reinsurers purchase what they perceive to be the necessary reinsurance cover. Thus, if a loss occurs that is greater than the sum of all the insurers' and reinsurers' voluntary retentions, *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.[27] 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

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, that is, 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 Di, $i = 1....m$, and let it purchase reinsurance Ri. Let Rij be the reinsurance cover purchased by

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[22] In the absence of co-insurance.

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

[24] 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 or co-insurance.

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

[26] Including any consciously unprotected layers of cover.

[27] Of course, PML failure may also be due to insurers underestimating the maximum amount of the original losses.

the i'th reinsurer from the j'th reinsurer ($i = 1 \ldots (m+1)$).[28] Since no reinsurer purchases cover from itself, it follows that:

$$Ri = \sum_{j=1}^{m+1} Rij \qquad Rii = 0.$$

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

$$\sum_{i=1}^{m} Rij$$

and the cover provided by the outside reinsurer is:

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

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

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

$$Xi[Rij/Ri], \ j = 1, \ldots, (m+1)$$

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

$$\sum_{i=1}^{m} Xi[Rij/Ri], \quad j = 1, \ldots, (m+1).$$

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

$$Xj + Dj + \sum_{i=1}^{m} Xi[Rij/Ri], \text{ and provided that}$$

$$Xj + \sum_{i=1}^{m} Xi[Rij/Ri] < Rj$$

it is entitled to recover a further

$$\sum_{i=1}^{m} Xi[Rij/Ri]$$

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

$$\sum_{i=1}^{m} Xi[Ri, (m+1)/Ri]$$

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

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

$$\sum_{j=1}^{m}[Rij/Rj]\sum_{i=1}^{m}Xi[Rij/Ri]$$

with

$$\sum_{j=1}^{m}[Rj,\,(m+1)/Rj]\sum_{i=1}^{m}Xi[Rij/Ri]$$

falling on the outside reinsurer.

This process continues until one of the following occurs:

1. The total claims on the outside reinsurer amount to $\sum_{i=1}^{m}Xi$ – i.e. to the total insured losses covered by the inside reinsurers less their deductibles – before any inside reinsurer has exhausted its reinsurance cover, Ri. In this case, the cumulative claims on the i'th inside reinsurer cannot exceed $Ri + Di$, 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 *all* 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.

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 analytical 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,[29] 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 $R_2 (R_2 > R_1)$

[29] This involves no loss of generality. If n is large the fact that reinsurers do not place any reinsurance directly with themselves can be ignored.

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 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 insurer 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

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

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*.[30]

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

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

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.[31]

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[30] 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 $\alpha R_0[1+1/\alpha] = R_0[1+\alpha]$.

[31] At this point the total claims generated by each inside reinsurer amount to $R_0[1+\alpha] + [R_1 - R_0] = [R_1 + \alpha R_0]$.

However, the two groups of insider reinsurers are now in different positions. The first group have run out of reinsurance cover, and have to retain 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 $[\beta_1/\beta_1]Z$,[32] 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

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

and by the second group are

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

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 \$1200 million.

Suppose that it is provided by 200 insurers (the insiders), each of unit size, who provide \$6 million of cover each. Suppose further that each inside insurer retains the first \$1 million of loss and buys XL reinsurance (in layers) to cover the other \$5 million of potential loss. The first three layers of \$0.5 million reinsurance are spread equally amongst each of the inside insurers and 100 outside reinsurers (i.e. $R_0 = \$1.5$ million), while the next \$3.5 million are provided equally by all the insiders ($R_1 = \$5$ million). Finally, suppose that 50 of the insiders (group 1) do not purchase any further reinsurance, but that the other 150 (group 2) purchase

[32] 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 $[R_2 - R_1]$.

additional reinsurance cover up to \$10 million ($R_2 = \$10$ million), this being provided equally by all the insiders.

Figure 1 shows the loss retained by each insurer if an insured loss of \$X million is incurred.

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

Figure 2 illustrates how the total level of claims is magnified in the course of the spiral. Since the first \$200 million 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 \$200

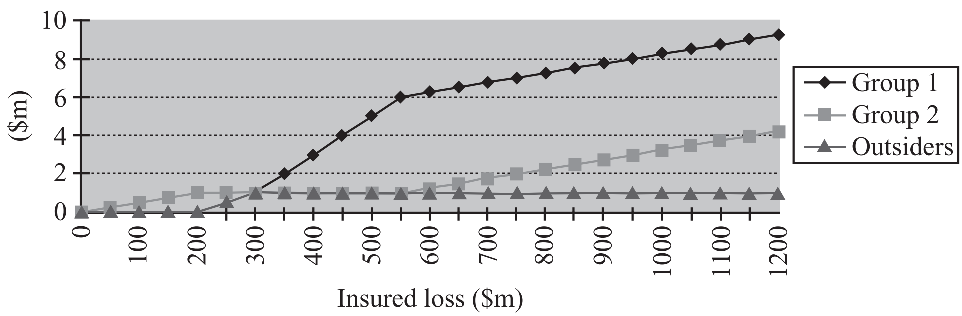

Figure 1: Incidence of loss

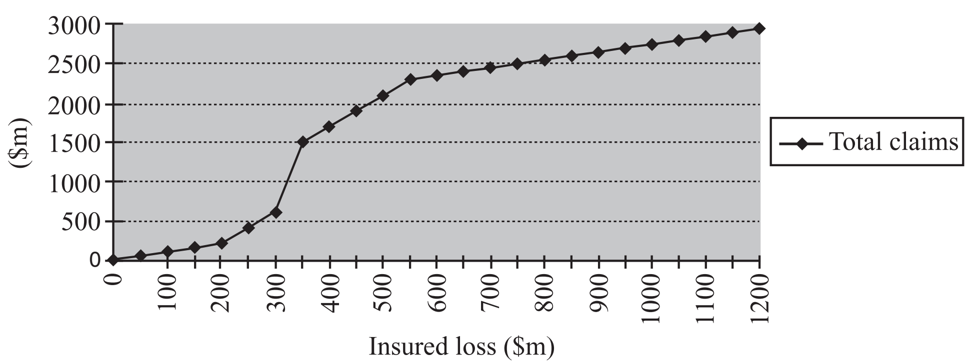

Figure 2: Total claims

million and $300 million, only one-third of any reinsurance claims are retained by outsiders, with the balance leading to further claims – in this range the addition to claims is four times the additional insured loss, so that an insured loss of $300 million generates total claims of $600 million. At this point total claims rise precipitously – by another $700 million – before any further losses are retained (for example, insured losses of $301 million would generate total claims of just over $1300 million). Further losses in the range $300 million to $550 million generate claims amounting to four times the additional losses, taking the total of claims to $2300 million. Since insured losses of $550 million 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.

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 on page 235 above. However, there is also a fourth group to consider: inside reinsurers who accept layers of reinsurance up to one level but who 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.[33]

It is worth 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 this may occur.

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.[34] 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 Figure 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

[33] Since reinsurers in this fourth category provide capacity only to the extent that they retain risk themselves, the volume of claims in the spiral is inflated by the amount of the reinsurance purchased.

[34] If 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.

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[35].

If the existence and implications of spiral business are not fully recognized 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 risklessly by placing high layers of reinsurance at premiums lower than they can obtain for the lower layers they themselves accept.[36]

4. The London Market insurance spirals

It is not difficult to point to a number of features of the London Market in general and Lloyd's in particular 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:[37] in terms of the simplified model on pages 235–37 above, 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 London Market underwriters "retained a very low retention and bought reinsurance to improve their premium to risk position"[38]: in terms of the general model of pages 233–35 above, D was frequently very small. As a result, even moderate losses were likely to exceed underwriters' deductibles 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",[39] or because they regarded

[35] See Insurance Institute of London (1988): ". . . 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).

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

[37] "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.)

[38] Walker (1992, paragraph 2.15).

"the higher layers of cover ... as virtually risk-free"[40]. 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 on page 235 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",[41] "demands for reciprocity",[42] and financial constraints on the amount of premium income spent on reinsurance.[43] Their position may be compared to that of the first group of reinsurers on page 235 above.

Fifthly, the premium structure for successive layers of spiral business did not reflect the true risk of loss: "the upper layers ... were grossly underrated".[44] 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,[45] as suggested on pages 239–40 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 London Market insurance spirals of the late 1980s, and they invite the question as to how a repetition of the spiral phenomenon can be avoided in future. While this is clearly a matter for the insurance industry and their regulators to consider, the analysis in this paper may provide some useful pointers.

First, catastrophe reinsurance and retrocession is a complex, high volatility, specialist business which can be conducted safely only by those with the requisite expertise. Insurance company directors, and their counterparts at Lloyd's with influence over the deployment of capital, should not allow themselves to be seduced again by apparently high short-term profits or permit underwriters without the necessary expertise to dabble in this kind of business.

Secondly, underwriters should adhere to the core principle of underwriting only when they have sufficient information to make an objective assessment of risk and to rate risks accordingly. That in itself would eliminate most spiral business, which lacks the necessary transparency, and would reduce the likelihood of the development of an irrational pricing structure. In order to adhere to this principle certain categories of business might have to be excluded from whole account retrocession cover.

Thirdly, if retrocession underwriters were to insist on a significant element of co-reinsurance by their reassureds, the latter would be unable to participate in spiral business without the discipline of exposure to additional risk, and the incentive to profit from an irrational pricing structure, and in so doing to exacerbate the spiral, would be reduced.

Finally, while regulators cannot be expected to have 20/20 vision, they do have an

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

[40] Phillips (1994, p. 86).

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

[42] 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".

[43] Phillips (1995, pp. 54–55).

[44] Phillips (1995, p. 108).

[45] Phillips (1994, p. 68).

obligation to be aware of market developments and to take action to control market behaviour that gives rise to obvious systemic risks.

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