

Reinsurance Market Microstructure
Topic: Pricing Risk

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Abstract

Capital market microstructure analysis is the study of (i) price formation and discovery—how latent investor demands are translated into realized prices and volumes; (ii) market structure and design—relation between price formation and trading protocols; and (iii) information and disclosure—transparency, the ability of market participants to observe information about the trading process. By studying the market microstructure, and in particular the *order book*, where bids and offers are managed, the mechanics of price movement, liquidity, and market depth can be understood. Of particular importance, investor risk preferences and aversion, usually assumed away in efficient market theory, emerge as critical drivers of order book density and depth, and therefore liquidity and price movement.

This paper will first provide a brief overview of capital market microstructure, then explore reinsurance market microstructure. The focus will be on (i) how the fundamental auction characteristics differ from the capital markets, (ii) the reinsurance order book, and (iii) reinsurance price movement and market liquidity.

Keywords: reinsurance, market microstructure, bid-ask spreads, investor risk preference, market frictions

1. Capital Market Microstructure

Market microstructure is a large and rapidly growing area of research into how investors' demands are translated into transactions or trades. Market microstructure analysis has grown in tandem with increases in technical and computing capabilities. Analyses of millions of individual transactions were inconceivable in the 1960's and 1970's when much of the efficient market paradigm was being fleshed out. Researchers back then had to make simplifying assumptions particularly in the mathematics. One of those critical assumptions is that there is "a price" at any given time for a security, and that this price essentially moves in a nearly continuous but random manner. This is essentially the "Geometric Brownian Motion" model.

Today's computing power and detailed investment tracking databases have allowed us to "slow down the movie" and actually look at the moving atomic parts which result in trades. Trades are the raw material for financial market researchers. In fact, trades are said to "reveal" prices. This choice of terminology suggests the continuous Brownian motion exists in and of itself. The human element plays no part here. Traders are akin to detection devices, monitoring and sampling an underlying reality.

But trades occur between two counterparties, be they institutions or individuals. Presumably trades occur because both parties believe the trade to be beneficial. "Beneficial" is a purely subjective assessment, based on individual interpretation of past, present and future information. Trading also occurs in an auction framework, and involves negotiations, patience, and alternatives. The structure of the auction itself can influence the outcome.

One of the best surveys of market microstructure is Madhavan [2], which outlines the field of study as follows:

"(1) Price formation and price discovery, including both static issues such as the determinants of trading costs and dynamic issues such the process by which prices come to impound information over time. Essentially, this topic is concerned with looking inside the "black box" by which latent demands are translated into realized prices and volumes.

(2) Market structure and Design Issues, including the relation between price formation and trading protocols. Essentially, this topic focuses on how different rules affect the black box and hence liquidity and market quality.

(3) Information and Disclosure, especially market transparency, i.e., the ability of market participants to observe information about the trading process. This topic deals with how revealing the workings of the black box affects the behavior of traders and their strategies.

(4) Informational issues arising from the interface of market microstructure with other areas of finance including corporate finance, asset pricing, and international finance. Models of the black box allow deeper investigations of traditional issues such as IPO underpricing as well as opening up new avenues for research." ([2], p. 3)

Most modern financial markets follow a format known as the *continuous double auction* (CDA). "Continuous" means that while markets are open for trading, any type of offer can be made at any time. In the CDA, there are two types of orders:

- Market orders: requests to buy or sell a given number of shares immediately at the best available price (usually associated with impatient traders); and
- Limit orders: worst allowable price to transact within a given time limit; not always immediately transacted, limit orders are stored in a queue known as an *order book*.

Buy limit orders are known as *bids*. Sell limit orders are known as *asks* or *offers*. At any given time, there exists a best (lowest) ask price (we will call ASK) and a best (highest)

bid price (BID). The difference is called the *bid-ask spread*. Market microstructure analysis highlights the lack of a precise definition of “market price.” *Midprice*, the average of BID and ASK, is often used as the best available proxy¹.

Beyond just being a scalar representing the cash amount, each bid or ask also has an associated volume (number of shares) and time limit. The volume represents the market depth, an important characteristic in assessing market *liquidity*. Per the “Investors Dictionary,” liquidity is “the ability to quickly buy or sell a particular item without causing a significant movement in the price.”²

Examples of the four types of orders:

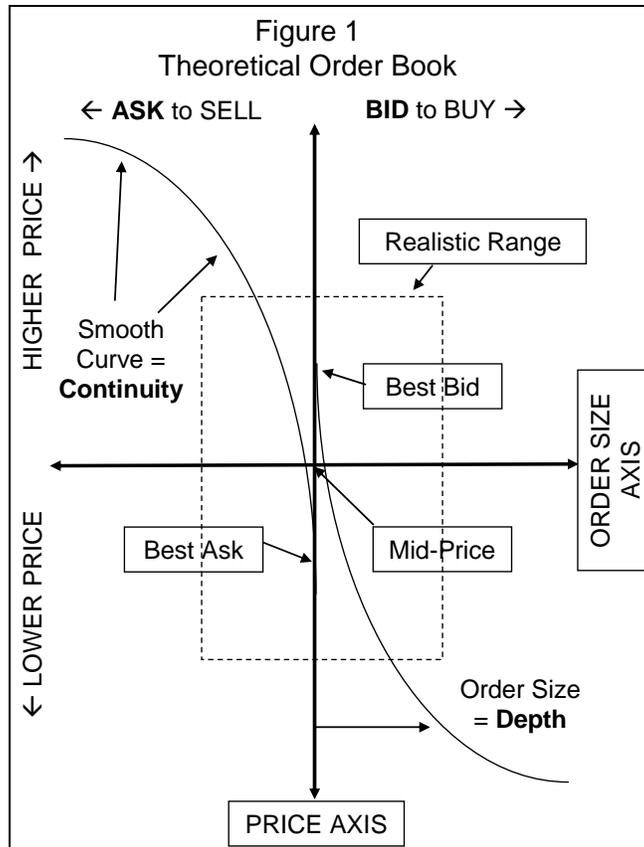
- Limit Bid: “Buy 100 shares if anyone is willing to sell at a price of \$50 or less before 4:00 p.m. today.”
- Limit Ask: “Sell 100 shares anyone is willing to buy at a price of \$60 or more before 4:00 p.m. today.”
- Market Bid: “Buy 100 shares at the best (lowest) possible price as soon as possible.”
- Market Ask: “Sell 100 shares at the best (highest) possible price as soon as possible.”

1.1 Theoretical Order Book

In market microstructure theory, the order book is assumed to be (i) continuous (no price gaps) and (ii) deep (able to satisfy any market order without what is called *price impact*—more on that in a moment). One such theoretical order book exists for each security. Figure 1 is a graphical depiction of a theoretical order book.

¹ Leslie Rahl of Capital Markets Risk Advisors presented on the potential pitfalls associated with the use of midprice in low liquidity markets. See www.erm-symposium.org/2005/erm2005/GS2_Rahl.pdf.

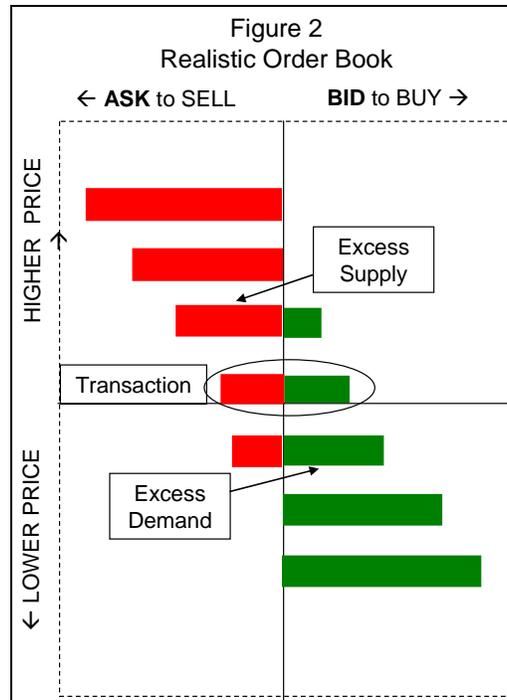
² www.investordictionary.com/definition/market+liquidity.aspx



The theoretical order book changes over time as bids or asks (also known as *quotes*) expire or are removed (cancelled), or orders are filled.

1.2 Realistic Order Book

Quoting costs and herding effects limit the realistic range to be within certain bounds of the mid-price—i.e., it is not feasible for market participants to produce infinite quotes for all possible prices for every traded security. Figure 2 focuses in on the realistic range from Figure 1:



Real order books are discrete not continuous for two main reasons. First, the order book itself is filled with individual orders or quotes. Second, there are minimum price increments, known as ticks, imposing a limit on granularity.

Each quote indicates willingness of an individual market participant (agent) to buy or sell. Transactions occur when a sell order (ask) is matched to a buy order (bid) in both price and volume.

Order books can also be *sparse*, which means having gaps. Market-making firms are supposed to fill out gaps in the order book, by for example filling a buy order at a certain price when no market participants have put sufficient sell orders at that price into the order book. Market making maintains market liquidity. In an active trading environment, market making is a low risk exercise, usually involving temporary holding of a security position net for a short period of time until a counterparty can be located. However, in low liquidity markets, market making can be a risky activity.

1.3 Price Movement in a Continuous Double Auction

An excellent reference on the mechanics of market price changes is “What really causes large price changes?” by Farmer et al, 2004 [1].

Figure 3 demonstrates the mechanics of a price drop during a mini “liquidity crisis” sell off in our simplified example order book.



A liquidity crisis (sell off) occurs when there are not enough buyers (bids) anywhere near the mid-price. Sellers have two choices:

- **Be patient:** hold the asking price constant, wait for the market to stabilize and liquidity to return. This approach assumes it is a temporary market failure and that eventually an agent will express interest in buying the shares at the asking price.
- **Be impatient:** lower the asking price to a level necessary to match up to the first available bid order.

However, each lowering of asking price demonstrates impatience, which creates incentives for buyers to cancel existing bids and put out new, even lower bids. This lowering of bids in response to seller impatience is the mechanics of a *price drop*. The mirror-image process similarly explains price increases.

A high density of limit orders per price (i.e., a “full order book”) results in high liquidity for market orders. Per the definition of liquidity, a full order book should imply a small movement in the best price when a market order is placed. Liquidity is really a measure of market depth and continuity. Depth means the amount of shares available, while continuity implies orders are close together, not spaced far apart (sparse). Low liquidity can lead to large price movements when filling orders.

Figure 4 shows how liquidity and price movement interact in a CDA:

Figure 4
Liquidity and Price Movement Example

Filling a Market Sell Order for 600 Shares
Under Low Liquidity and High Liquidity

Low Liquidity Order Book					
Pre-Transaction				Post-Transaction	
Bid #	Bid Price	Bid Shares	Shares to Fill Market Order	Bid #	Bid Price
1	35	100	100		
2	34	200	200		
3	33	300	300		
4	32	400		4	32
5	31	500		5	31
Best Bid Price		35	→		Best Bid Price
					32

High Liquidity Order Book					
Pre-Transaction				Post-Transaction	
Bid #	Bid Price	Bid Shares	Shares to Fill Market Order	Bid #	Bid Price
1	35	600	600		
2	34	600		2	34
3	33	600		3	33
4	32	600		4	32
5	31	600		5	31
Best Bid Price		35	→		Best Bid Price
					34

The left panel shows a low liquidity order book. It is shallow, in that all bids are for 200 shares only. The best bid is \$35, but that is a bit deceptive since the order is only for 200 shares. A seller looking to liquidate 600 shares will need to fill three bid orders (#1 - #3), for \$35, \$34 and \$33. After this, the order book only has bids for \$32 and \$31, making the new “best bid” \$32. Thus the “best bid price” moved from \$35 to \$32 in the low liquidity order book.

The right panel shows a higher liquidity order book. The order prices are the same as in the low liquidity example, but the orders are deeper—all being for 600 shares. So the seller looking to unload 600 shares need only fill the first bid at \$35. The remaining order book “best bid” only moves to \$34, a much smaller price impact than under low liquidity.

This example demonstrates how price movement is impacted by liquidity—market sparseness and depth. Order book density is the granular representation of investor demand, literally appetite for the security. An investor who believes a stock is overvalued will add very low limit bids, at prices at which the investor would be pleased to purchase the stock. If no seller emerges before the expiration time, the offer is cancelled.

1.4 The Mechanics of Arbitrage

The Investors Dictionary defines *arbitrage* as³ a “trading strategy that looks to take advantage of price differences of the same security, currency or commodity, trading on different exchanges...arbitrage trading may also refer to trading on price differences between stocks and the underlying stock index options or futures.” The general colloquial definition of arbitrage is “no free lunch”—that is, no riskless profit opportunities.

³ www.investordictionary.com/definition/arbitrage.aspx

Efficient markets are assumed to quickly *eliminate* arbitrage opportunities that arise. Microstructure analysis provides us with the mechanics of that elimination—matching of bids and offers.

A simple example of an arbitrage opportunity would be share price differences for a given security in two different exchanges. Microstructure analysis has shown that no single “price” for a security in fact exists, just bids and offers for specified numbers of shares. However, if a bid to buy for say \$50 in one exchange could be matched to an offer to sell for \$45 in another exchange, and the physical transfer of the security could be effected, a quick enough arbitrageur could earn a riskless \$5 profit per share. This type of arbitrage opportunity is information driven—the sellers in one exchange were not keeping their offers current with the bids in another exchange.

2. Reinsurance Market Auction Structure

Many insurance risk theorists have tried to apply the complete and efficient market propositions to the insurance and reinsurance market. A cornerstone of this approach is the Law of One Price, stating that there is a single, observable price at any given time for a traded security. In fact, it is this assumed single price that drives many of the no arbitrage arguments.

Market microstructure analysis makes clear that this assumption is a convenient abstraction which is not supported by detailed capital market transaction data. The existence of a continuous double auction for securities generally constrains bid and ask prices to stay within reasonably tight bounds. The law of one price also only applies security by security. Similar or *comparable* securities only approximately obey the law, and often exhibit persistent price differences which arbitragers regularly exploit.

There are structural similarities and differences between the CDA and reinsurance market auction (RMA). Structurally the RMA is a one-way blind auction. It is one-way because insurers are only buying reinsurance protection from reinsurers, not selling. It is blind because reinsurers submit their asking prices without knowing what their competitors are asking.

There are two types of RMA orders⁴:

- Bid: price a cedant wishes to pay for reinsurance (note only one bid), and
- Quotes (Asks): price a reinsurer offers to sell the reinsurance.

Reinsurers do not bid, only ask; and there is only one bid, from the cedant itself. There is an order book of asks maintained by the broker.

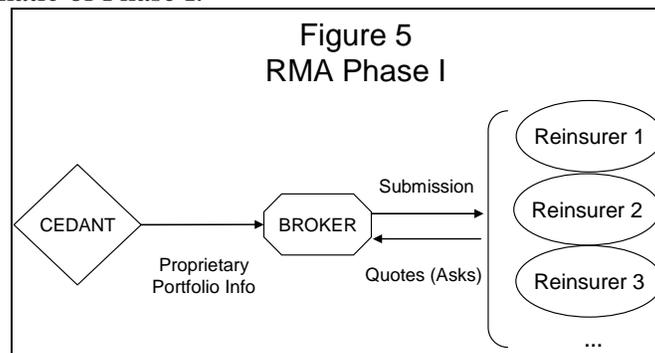
⁴ It is an arbitrary convention choice to say the cedant “bids” and the reinsurers “ask.” The opposite convention would work equally well.

The RMA is not continuous in time but timed (with effective dates and renewal cycles). It might be characterized as a synchronized blind auction—that is, with no way to see either the bid or the other asks. Individual reinsurers are never shown the other asks.

To simplify the analysis, we will consider large treaty placement in the broker reinsurer market. We will decompose the RMA into three distinct phases: (I) Price Exploration and Quote Development, (II) Asking Price Development, and (III) Firm Order Terms.

2.1 Phase I: Price Exploration and Quote Development⁵

Figure 5 is a schematic of Phase I.



The RMA has a costly quoting process, involving actuaries and underwriters, reams of submission data, and application of proprietary loss cost and pricing models. While lacking an absolutely consistent definition, we will first discuss what is called the technical price (other names are benchmark or target price). This price is generally an internal number only, representing the reinsurer’s best estimate of:

- Layer loss costs (developed using their proprietary loss cost models),
- Internal expenses,
- Discounting (a function of both payment pattern and interest rate assumptions), and
- Profit margin (based on any number of possible capital or risk cost approaches).

The actual reinsurer asking price (quote)—the price sent to the market (broker) —will very likely not be equal to the technical price. There are many factors affecting the quote, including market reputation, recent quotes on comparable programs, client reputation, and history. We will call the difference between technical price and asking price the *strategy differential*.

The reinsurer’s quote is typically accompanied by an indication of desired or *authorized line size* or *share*. This value will typically be expressed either as an occurrence limit amount (e.g., \$10MM of a \$100MM program), a percentage share of the total occurrence limit, or a maximum amount of assumed premium. Authorized lines are the RMA measure of market depth.

2.2 Phase II: Asking Price Development

⁵ [4] is an excellent survey of catastrophe reinsurance quote development.

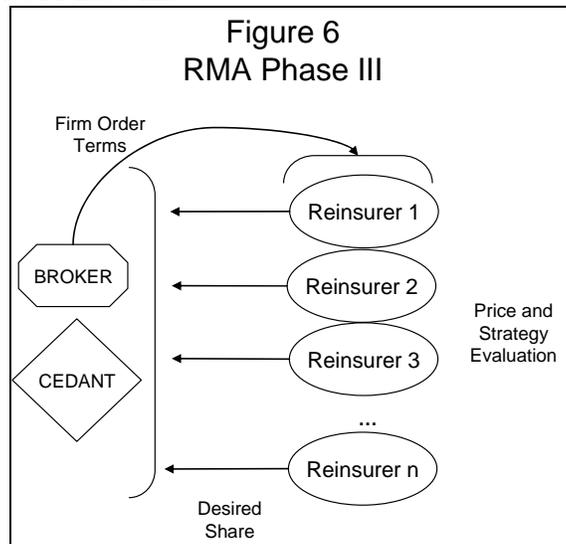
This step belongs to the brokers. They begin with the range of quotes and desired shares. They have the knowledge of the pricing for recent comparable programs. These *comparables* are similar to comparables used in the pricing of low liquidity investments of all kinds—real estate in particular, but also fine arts, distressed debt, and hedge funds.

Comparability is a powerful driver of RMA price movement in both directions. Brokers, being advocates of their cedant, use recent comparable programs placed at a price decrease to urge reinsurers to participate on the cedant’s program at a similarly reduced price. Conversely, as many property catastrophe cedants learned in 2006, reinsurers will use recent comparable price increases to drive up pricing on all programs.

Reinsurance comparability is difficult to assess, more so than higher liquidity financial products such as equities or bonds. Reinsurance is *opaque*; differences in insurance product lines, cedants, contract features, and underlying exposures mean comparability is approximate at best.

2.3 Phase III: Firm Order Terms

Figure 6 is a schematic of Phase III.



The end result of the broker’s efforts is the establishment of *firm order terms*, a finalized version of the contract including price and features such as commissions or profit sharing. The market depth will be a function of the degree of interest and appetite for participating on this cedant’s program.

The broker gauges where to set the final price to clear the market (get full subscription). If the final offered lines turn out to be much less than 100%, the bid price will have been set too low; if much more than 100%, the bid price will have been set too high.

The reinsurers must now *evaluate the given price* (firm order terms are not negotiable) and choose participation percentages (with “not at all” being an option). Because of the lack of market transparency and reinsurer communication, the decision is strategically

complex. If the firm order price is substantially below a reinsurer's technical price, or worse below the internal walkaway price, the underwriter must decide whether to be patient or impatient. A newly capitalized reinsurer with an empty portfolio and demanding investors must earn a return. If they *believe* they are running out of alternatives—the calendar approaching the end of the renewal period, brokers and friends in the industry telling them many of their competitors are willing to fill out the program—they may not believe they have the luxury of patience. In order to transact, they must “lower their *effective* asking price” and sign on the program.

2.4 Arbitrage in the RMA

Due to its structure, the RMA lacks arbitrage opportunities. There does not appear to be any mechanism to exploit arbitrage opportunities. In the first place, in such a low liquidity market, the identification of a *possible* arbitrage—say, grossly underpriced reinsurance—takes many years, and involves a bespoke contract arrangement between the cedant and the reinsurers. The final value of this reinsurance contract is also not public knowledge, so *traded derivatives* are unavailable. *Short-selling* (a typical means of exploiting arbitrage opportunities in the capital markets) is also not possible.

One could ask whether the RMA might punish a reinsurer whose asking price is wildly divergent from the consensus range of quotes. There are many reasons why the asking price from “Over-Priced Re” might be much higher than the others:

- Its technical price is much higher, due to a higher indicated layer loss cost, higher internal expense requirements, or a higher profit load;
- Its strategic differential is very high, due to a desire to nudge the final price upward or indicate weak interest.

The RMA results for Over-Priced Re: a low (or no) share being offered.

Similarly, “Under-Priced Re” could quote much lower than the others for several reasons:

- Its technical price is much lower, due to a lower indicated layer loss cost, lower internal expense requirements, or a lower profit load;
- Its strategic differential is very low (even negative), due to a desire to nudge the final price downward or indicate strong interest.

2.5 Price Movement in the RMA

It is more difficult to see “the price move” in the reinsurance market for several reasons:

- Fewer data points—programs renew annually;
- Imperfect comparability—for the reasons cited above;
- Auction structure—no short-selling, auction structure, low transparency.

It is even difficult for a cedant to evaluate the price movement in the renewal of a program with an essentially identical structure. After adjusting for differences in exposure, limit and retention, the renewal firm order price can differ from the expiring program price due to changes in asking prices and/or authorized shares. If the market interest in renewing at the expiring price is tepid, the cedant should be prepared to

increase its firm order price in order to clear the market. If the new price level is unacceptably high, some cedants opt to *short place* the program—that is, place only a fraction of the desired limit, as much as they can at the lower bid price.

Technical price changes can be of two sorts: idiosyncratic and systemic. An idiosyncratic change is isolated to one reinsurer, whose asking price is far out of step with expiring quotes, comparables or peers. This differential might result from innovations in proprietary loss cost estimates, increases in internal expense or profit load requirements. However, since these changes are isolated to a single reinsurer, their impact on the range of quotes and eventually the firm order price is limited.

Systemic technical price changes are common across many reinsurers. They are primarily driven by:

- Industry-wide loss cost shocks—e.g., U.S. general liability in 1986 after the wave of pollution claims hit;
- Industry-wide profit load shocks—e.g., post September 11, 2001, when the reinsurance market price of risk increased across the board for all lines of business.

Considering the second dimension of liquidity, market depth, the reinsurance order book may be shallower if reinsurers are either wary of their own ability to properly price the cover or if they believe the underlying primary business is itself so underpriced that it cannot support the technical reinsurance pricing. In such a case, the cedant will see capacity—authorized lines—dry up. Reinsurers' consensus risk opinion of a product line is expressed in the breadth and depth of the order book.

3. Reinsurance Liquidity Crisis: 2006 U.S. Catastrophe Reinsurance⁶

2004 and 2005 were two of the worst years for catastrophe reinsurance ever, with seven of the ten costliest storms on record. The ultimate costs of Katrina, Rita, and Wilma may approach USD80 billion. Even worse for the reinsurance industry, a far larger percentage of those total losses were reinsured. More than 50% of Katrina's estimated USD38 billion were ceded to reinsurers.

In response to the anticipated hard (higher priced) market, capital flowed into the reinsurance industry in the form of either new firms or additional capital for existing firms. There was also increased usage of catastrophe bonds and the introduction of *investment sidecars*, special-purpose investment vehicles designed to provide additional capacity to an insurer during a rising market.

Given all this new capacity, one might have expected the 2006 U.S. catastrophe market to be well functioning or *highly liquid*. A highly liquid market is one in which participants enter or exit a position of any size, in a timely manner, and without undue price impact.

⁶ Facts on the 2006 U.S. catastrophe reinsurance market were drawn from [3].

In 2006, a “perfect storm” of influences led the U.S. catastrophe reinsurance market to what can only be called a *liquidity crisis*. U.S. insurers were unable to purchase reinsurance in the desired quantity at anything resembling the expiring prices. This situation was a systemic crisis, striking across the board. The RMA mechanics that led to this crisis were: catastrophe model changes, changes to rating agency capital formulas, and the loss of retrocessional capacity.

Catastrophe Model Changes

The U.S. catastrophe reinsurance market is heavily driven by catastrophe models. Reinsurers and brokers use the models for layer loss cost, program pricing and structuring. Insurers base their catastrophe reinsurance purchases on:

- Certain critical *return period PMLs* (probable maximum losses), such as the one-in-100 year and one-in-250 year loss amounts from the occurrence exceedance probability curve (OEP);
- Prior year reinsurance purchasing, often defined in terms of program *attachment* and *exhaustion* return periods; and
- Peer purchasing decisions, again in terms of return periods.

In practice, catastrophe reinsurance pricing is so heavily model driven that variations in quotes (asking prices) among reinsurers is greatly reduced, especially compared to property per risk or casualty programs. The main reasons for variations in quotes are internal expense loads (typically only a few percent of premium), profit load, and strategy differential.

In 2006, Risk Management Solutions (RMS), a major catastrophe modeling firm, introduced a new version of its U.S. windstorm model. The impact on key return period loss amounts was dramatic—in some instances increasing 50% or more. Not surprisingly, the modeled layer loss costs for expiring cat programs increased as well.

Rating Agency Changes for Insurers and Reinsurers

Rating agencies also changed their methodologies as a result of the severe hurricane season. In the fall of 2005, A.M. Best announced changes to its Best’s Capital Adequacy Ratio (BCAR) formula. The previous BCAR formula subtracted the after-tax impact of one net catastrophe PML (one-in-100 wind event or one-in-250 earthquake event). In mid-2005, A.M. Best introduced a *stress test* to monitor the impact of a second catastrophe event on the BCAR for all insurers. A.M. Best modified the stress test from a one-in-50 wind event or a one-in-100 quake event to a *one-in-100* wind event or a one-in-100 quake event. Reinsurers responded by reducing limits in high catastrophe zones, as well as attempting to move exposures to retrocessionaires, sidecars or catastrophe bonds.

Similarly, on March 21, 2006, Standard & Poor’s revised its criteria to include an exposure-based catastrophe capital charge for insurers, similar to the capital charges for reinsurers.

Retrocession

As a result of increased rating agency scrutiny, most reinsurers greatly curtailed their extension of retrocessional capacity for competitors—essentially selling reinsurance for reinsurers. The loss of retrocessional capacity meant reinsurers were far more constrained as to the *zonal aggregates* they could take on—the sum total of all occurrence limits outstanding in a given geographical zone, exposed to a given peril.

Results

The combined impact of these many factors can be summarized as follows:

1. PMLs increased – model changes meant the dollar loss associated with a certain return period increased dramatically.
2. Required purchasing increased – an insurer buying renewal coverage up to the expiring return period exhaustion point needed to purchase significantly more limit in absolute dollar terms. Also, due to increased rating agency stringency, an insurer may need to purchase coverage out to a more remote return period.
3. Layer loss cost estimates increased – increased frequency and severity meant all else equal, the expiring program quotes are substantially higher than expiring.
4. Available supply decreased – due to increased rating agency stringency and the loss of retrocessional capacity, reinsurers had strict limitations on the aggregate limits they could extend in a given region/peril.
5. Price for that reduced supply increased – due to the substantial deficits from 2004 and 2005, the owners of reinsurers targeted higher returns, which translated to higher profit margins underlying the quotes.

Liquidity Crisis

Many large U.S. insurers, with exposure across the country, were unable to place their desired programs. They could not buy the desired amount of limit even if they raised their bids. The liquidity shortage was not a price issue, but a capacity issue. Also, the supply of additional reinsurance capacity could not grow quickly enough. The alternative sources (cat bonds, sidecars) did pick up market share, but it was not enough.

4. Conclusion

Market microstructure analysis illuminates the practical limitations to the complete and efficient market theories dominating financial risk academia. These market imperfections are often dismissed as annoying anomalies that distract from otherwise elegant mathematics. However, the microstructure reveals the critical role that agent risk preferences play in liquidity and the actual movement of prices. When applied to the illiquid reinsurance market, the microstructure analysis highlights the building blocks of asking price variations and the mechanics of liquidity crises. It is hoped this analysis will show the importance of diversity of risk opinion, the importance of reinsurer risk assessment, and possible beneficial market interventions to help mitigate liquidity crises.

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