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Concurrent Simulation to Explain Reinsurance Market Price Dynamics

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Introduction

The property-casualty (P&C) reinsurance market, with fewer than 10 major players, is characterized by almost no product differentiation: production decisions are based on estimated product costs and prices, both of which are observed after significant time lags; there are low barriers to entry and established competitors are volume-constrained due to prior business. An agent-based model (ABM) is employed to provide insights into the dynamics of this market. The agent will be a reinsurer competing in a simplified market with other reinsurers. The simplifications allow tractability while preserving enough fundamental aspects of the market to make conclusions meaningful.

Each reinsurer will have the following key components: a book of business (with premiums and claims), a portfolio or collection of books of business, the aging of books (requiring establishment of reserves), required capital being generated by the books acting as a constraint on capacity for new business and a strategy for deciding how much capacity to offer each year. The interaction effect is introduced through a market demand curve that translates aggregate capacity offered into price.

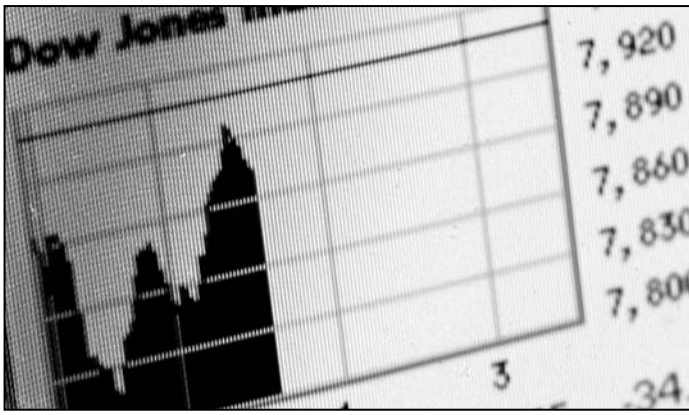
Even with these simplifications, the market shows instability leading to price cycles. This suggests: (1) instability is at least in part a function of strategic interaction effects, and (2) the relaxation of the simplified assumptions is not likely to reduce or eliminate the cyclicality.

Market Structure

Marketplace behavior has been extensively studied in monopolies, oligopolies and commodity markets. However, markets with three to 10 competitors are difficult to study from a theoretical sense. There are several reasons for this:

1. *Each participant influences the market significantly but none controls it.* Thus, we have a number of two-way interactions to consider. In a monopoly situation the single market participant controls the market and in a commodity market the participant has no influence on the market and dependencies are unidirectional.

2. *The feedback loop is not as strong as for two-player markets.* Any action a single participant takes affects a number of other participants. Retaliation for unwanted behavior is thus diluted and stable situations based on the fear of retaliation are fragile.



3. *Price wars are more likely.* This is due to the weak feedback loop and the number of actors. The more parties are involved, the higher is the chance that one tries to get away with a price cut. The other possibility to start a price war is the pure chance of a misinterpretation of some action.

4. A Nash equilibrium might exist, but is hard to obtain in reality. Besides the different issues listed above, there are always egos involved and varying goals.

The P&C reinsurance market, with fewer than 10 major players, falls into this category. In order to study this market we use a simulation based on only three market participants that replicates the key features of this marketplace. Some of these features are:

- Almost no product differentiation;
- "Production" (i.e., capacity) decisions made based on estimated product costs and prices, both of which are observed later;
- Low barriers to entry;
- Established competitors being volume-constrained due to prior business.

The reinsurance market has a well-known price cycle (See Figure 1 on page 14, Meier and Outreville 2003). The first question we wanted to answer using simulation was: "Can we

continued on page 14 ◗

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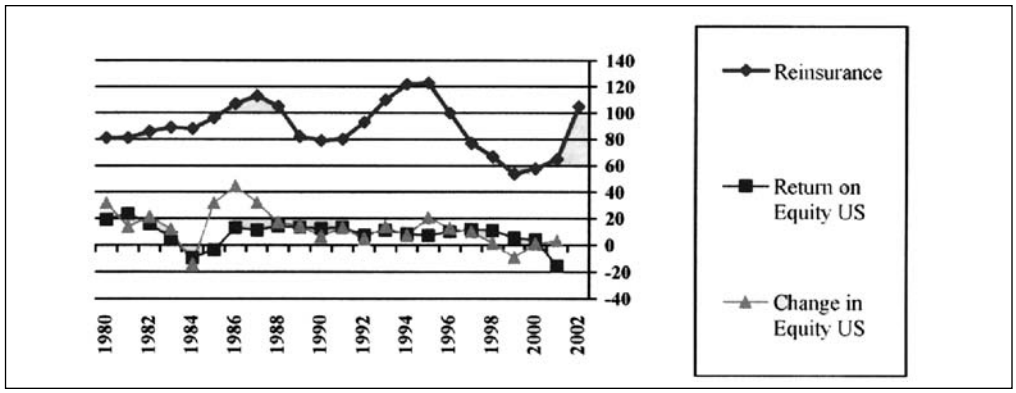
Concurrent Simulation...

◗ continued from page 13

Figure 1: Reinsurance Price Index and Equity
(Source: Swiss Re, 2002)



replicate this price cycle using just basic assumptions?" We decided to construct a simplified reinsurance market, with core dynamics sufficiently realistic to ensure meaningful learning. The characteristics we chose to model are listed below:

- Single product type with known expected cost;
- Single, known claims payment timing pattern;
- Underwriting capacity measured, and pricing determined, as a function of underlying exposure units.

In many respects, one could consider this to be an idealized reinsurance market. Actual markets deviate most acutely with respect to the expected costs and the exposure units. Costs are extremely difficult to accurately forecast. Moreover, these costs emerge over time, many years after the reinsurance sale is completed. Underwriting capacity is typically estimated using proxies for exposures—either premiums (the product of exposure units and rate per exposure unit) or reserves (the product of exposure units and estimated ultimate claim cost per exposure unit).

> "Each reinsurer agent is modeled following a fairly simple strategy of always trying to maximize its market share given its financial constraints."

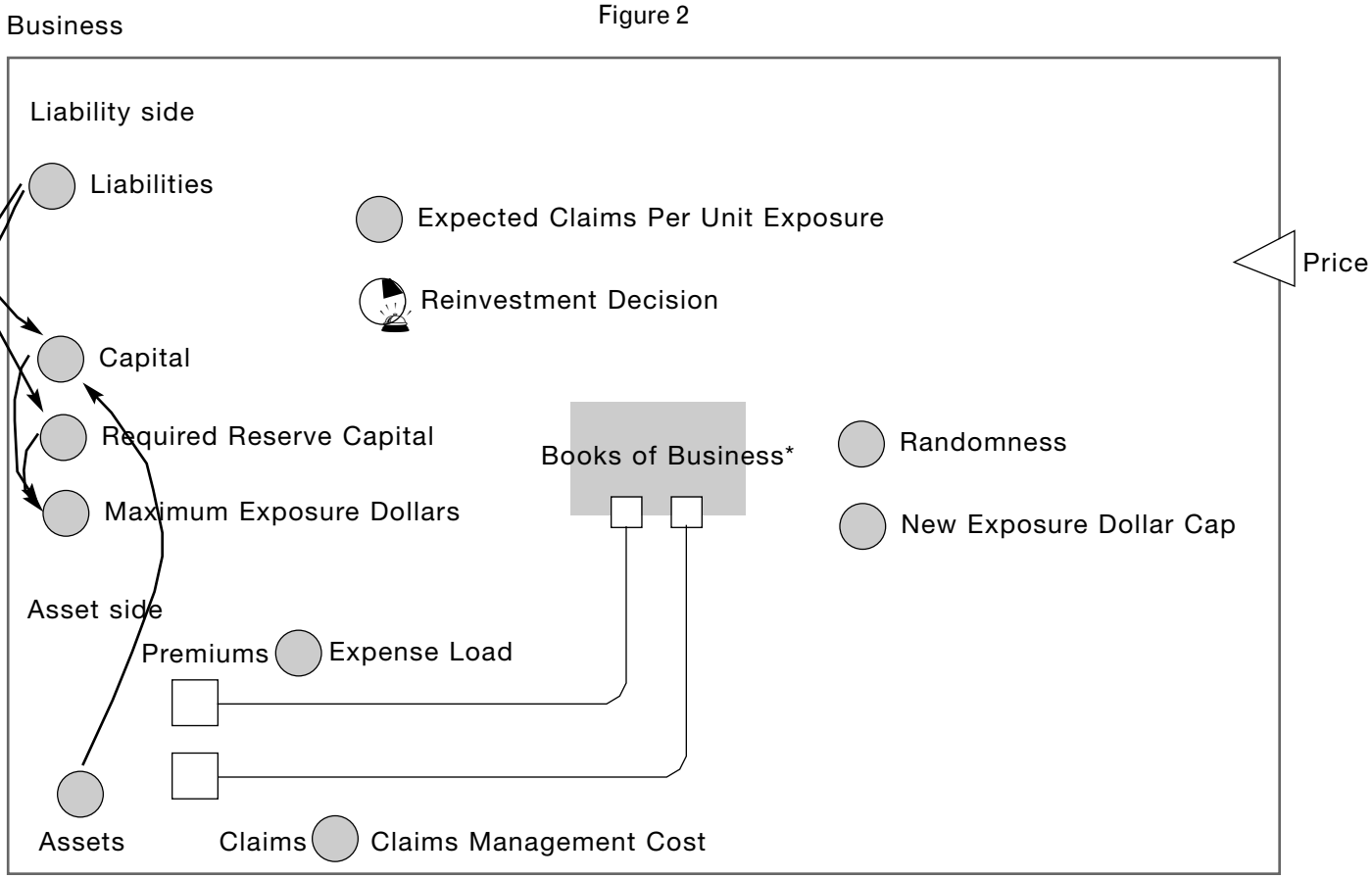
Agent-Based Modeling of A Reinsurer

An ABM is employed to provide insights into the dynamics of this market. Each reinsurer agent is modeled following a fairly simple strategy of always trying to maximize its market share given its financial constraints. The model is constructed using three reinsurers without any new entrants into the market.

The structure will be built up as follows:

- Reinsurance is underwritten into a *book of business*. Each *book of business* becomes an isolated object that is part of a reinsurer, and that communicates with the *reinsurer* object through ports—fixed points that receive the claims and the premiums generated by the individual *books of business*.
- Each book collects premiums and generates claims. As it is written, the following variables are established: number of exposure units (i.e., capacity underwritten), price per exposure unit and expected claims (loss costs) per exposure unit.
- Premium (revenue) = exposures * price per exposure unit.
- Total ultimate loss payments = exposures * claims per exposure unit.
- As the book ages, it establishes a *reserve liability*—a provision for the remaining claim payments. It is equal to the total ultimate loss payments minus the cumulative amount of loss payments to date.
- The model considers only a single type of *book of business* as characterized by the cash flows: all premiums are received in year one, while all claims payments are stretched equally over four years.
- The price depends on the market conditions, but the break-even price is

Figure 2



fixed at $400 per policy, the expected loss cost.

- A *reinsurer* (the business) holds a collection of *Books of Business*, known as a portfolio.
- A reinsurer is a financial entity with assets and liabilities. The liabilities are the sum of the reserve liabilities for the books in the portfolio.
- The assets increase for premium, and decrease for expenses and claims payments.
- The difference between assets and liabilities is the capital.

Figure 2 shows the major elements of the reinsurer agent.

Capital gives the reinsurer underwriting capacity—the ability to take on units of exposure. The constraint on underwriting is *required capital*, which is implemented here as factors multiplied by exposures. The reinsurer can only underwrite exposure units until its *capital adequacy ratio* (CAR)—actual capital divided by required capital—hits some constraint value (e.g., 200 percent). Typically, the constraint is a function of the reinsurer's desired counterparty rating as given by one of the rating agencies (e.g., Standard & Poor's, A.M. Best).

Simplified Reinsurance Market

Once a year each reinsurer will be asked for its *offered capacity* (expressed in exposure units = number of policies), in what is known as the reinvestment decision. We assume only one product type is available, with a known expected loss cost of $400 per exposure unit. The model assumes that each of the three reinsurers bids the maximum exposure units allowed subject to its maximum CAR. The bidding is simultaneous and blind—each reinsurer knows only its own bid. The resulting market price is a function of the aggregate capacity offered by all three agents combined, and is revealed after the bids are submitted. A simple demand curve (see Figure 3, p. 16) is used to determine this market price.

continued on page 16 ◗

Concurrent Simulation...

◗ continued from page 15

During the initialization phase, each reinsurer is given some assets and a starting *book of business*. However, these are not in equilibrium. We allowed 60 cycles of ramp-up for the market to reach a quasi-stable state, characterized for each reinsurer by:

- Assets ~$190 million;
- Liabilities ~ $100 million; and
- Capital ~$90 million.

At period 60, we introduce a *catastrophe* that wipes out approximately 20 percent of the capital of each reinsurer. We observe what happens to the prices over the next 20 years (see Figure 4). As one can see, the prices show a dramatic price cycle with a cycle time of approximately five years. The cycle time does not seem to depend on the time period over which claims are paid out (and liabilities exist) for a given *book of business*, nor the shape of the demand curve. Instead, it is a function of other model construction parameters. The demand curve slope around the $400 (break-even cost) price influences the degree of damping observed. By modifying the demand curve, one can create scenarios in which price fluctuations escalate over time or are dampened out. The critical insight: even with many simplifying assumptions (e.g., known expected loss cost), the interaction effects of the strategies themselves introduce cyclical market behavior. One could speculate that the relaxation of the simplifying assumptions would in all likelihood not act to dampen or reduce the cyclicality.

Making The Simulation Interactive

The first generation simulation featured only simplified capacity usage strategies for each reinsurer. In a second generation of the simulation we wanted to introduce more complex strategies. Two possible paths are: (1) to design and implement complex strategies into the reinsurer agents themselves (one could even use learning reinsurers) or (2) to have people take the role of the reinsurers. In order to encode strategies into an agent, the mechanics must be well understood by industry experts who can dictate formulaic rules to a programmer. This was not the case. In fact, one ancillary use of this model would be to teach reinsurer management teams about the impact of various capacity deployment strategies. So the second option was the only realistic one available to us.

We therefore developed an interface that presents, once per time period, the relevant reinsurer financial information and price history to each player. The players review the presented information, then make and submit volume decisions blind to each other. Once all decisions are submitted, the price is calculated and revealed, and the new *books of business* are created for each reinsurer. The model progresses one cycle (one year), then the players are presented

Figure 3

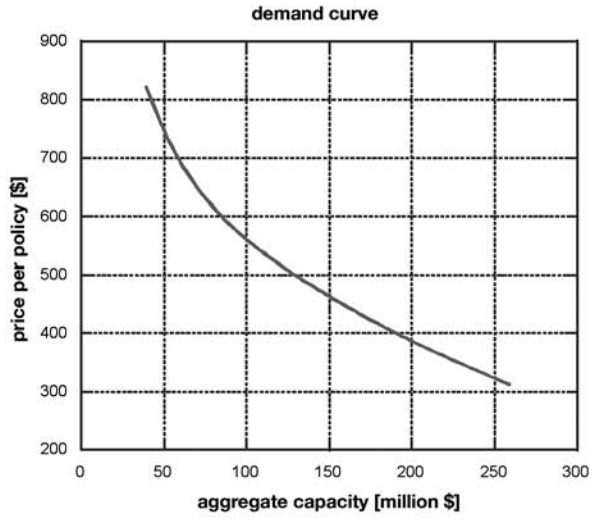
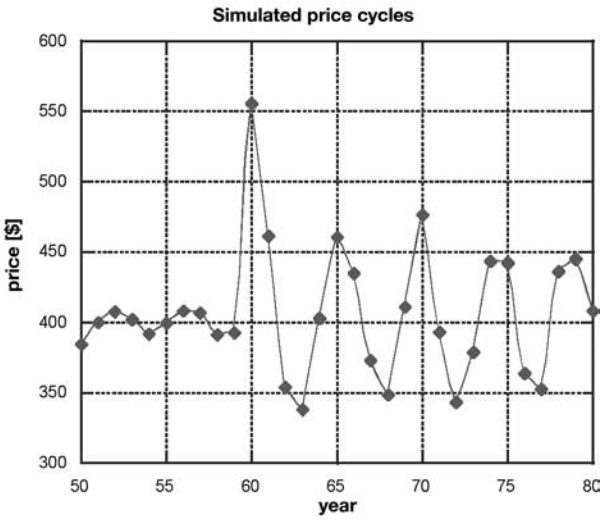


Figure 4



with the new information to review and decide on, and so on. This tool was found extremely helpful in communicating the market dynamics and decision implications to decision makers.

In the next generation, the tool was taken a step further to create more realistic scenarios (see Figure 5):

- Three types of products (known as "lines of business") were introduced, with varying claims payment profiles. These can be seen on the right side of the input screen, referred to as Short, Medium and Long (as in time horizon to complete claims payments).
- Each player is given the choice to allocate capacity among the three different lines in hopes of maximizing profit from capacity usage.
- Changes from period to period to the percentage allocation devoted to one line of business are constrained to be no greater than +/- 20 percent. This is a realism constraint reflecting the market reality that your "mix of business"—the percentage composition of your portfolio over all available product lines—cannot change too dramatically period to period.

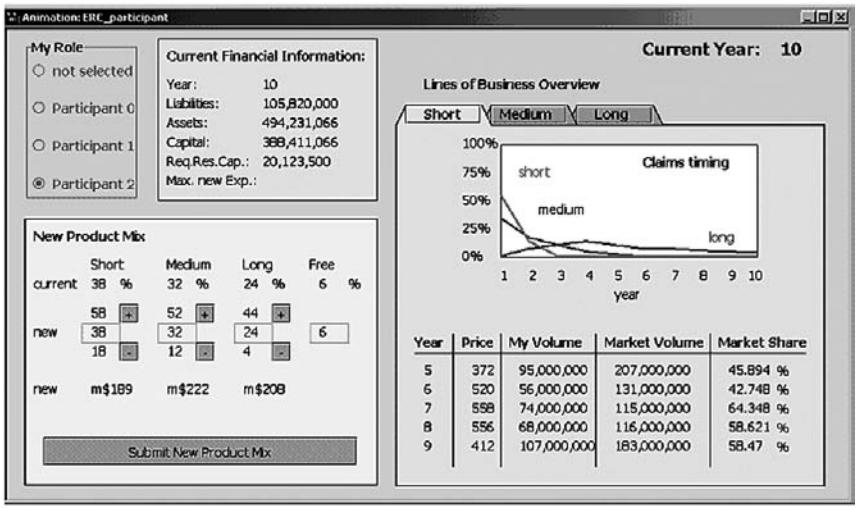
These changes increased the realism of the model, yet introduced additional moving parts that substantially increased the complexity of the dynamics. The clarity of the feedback, and therefore the learning opportunities for the target audience, were reduced. This clearly demonstrates the trade-off, particularly in ABM, between realism and comprehensibility.

Conclusions and Areas for Further Research

A model of the reinsurance market with three reinsurers was developed. Despite the simplifying assumptions made, the model exhibited a price cycle behavior similar to the one observed in the real marketplace. It is thereby concluded that the real world price cycles are due in part to the mechanics of the market place and the interaction of participant strategies. A parallel conclusion was indicated by the work of Farmer and Joshi (2002) using a simplified capital market.

Although we set up the model to dampen out price fluctuations over time and employed a "catastrophe" to trigger price swings that we could then observe, the actual trigger that starts the price fluctuations doesn't seem to matter. The key learning is that the market itself is not stable against any trigger.

Figure 5



In an attempt to bring these learnings to the decision makers, the simulation was modified to include more real-world complexities. We also allowed the decision makers to interact using the simulation with their peers in a virtual fast paced environment where a business year can be reduced to seconds.

For immediate next steps, we do not see tremendous benefit in adding more complexities to the model. While it may give more apparent accuracy and realism, it will provide only limited further insight, and may actually confuse the situation by muddying the signal. However, automated strategy development and strategy robustness testing using the tool are likely fruitful avenues. By playing multiple scenarios with varying parameters and counter-strategies, strategy robustness can be assessed. ✦

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