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**Using the Public Access DFA Model:
A Case Study**

Submitted by

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Using the Public Access DFA Model: A Case Study

Abstract

This paper describes the application of a publicly available property-liability insurance DFA model to an actual insurance company. The structure and key parameters of the model, as well as how to run the model, are explained in detail. A copy of the report to management of the company is included. The initial company reaction to this model was favorable. Management intends to use the model for such purposes as long term planning, capital allocation, reinsurance negotiations, competitor analysis and external communications with the regulatory and investment communities.

This paper describes the application of a DFA model to an actual insurance company. One goal of this work is to help actuaries learn about DFA by observing the use of a working model in a realistic setting. The model described in this paper is publicly available and accessible over the Internet. The company that generously allowed its data to be used in this exercise has asked to remain anonymous. Thus, minor modifications have been made to the data to help preserve the anonymity of this insurer. These changes do not affect the operation of the DFA model or obscure the data gathering process involved in running a DFA model.

Introduction

The DFA model used in this paper, termed Dynamo2, was developed by the actuarial consulting firm of Miller, Rapp, Herbers, & Terry, Inc. The model is accessible via their website (www.mrht.com) and requires only Microsoft Excel and @Risk in order to run. For those without access to @Risk, a limited version of the model can also be run solely in Excel. The Excel version is also useful for running a small number of iterations quickly to check the reasonableness of input values.

The general purpose of this model is to simulate a large number of possible outcomes from specific input data. By viewing the expected values and distributions of key variables, such as statutory surplus, premium-to-surplus ratios, and net income, the user can determine if these results are acceptable. If they are, then they validate the operating strategy of the company, subject to the general caveats of using DFA models. If not, then management can vary the input values to learn which changes would be effective in improving results to an acceptable level.

The model, when run using @Risk, allows the user to examine any of the stochastic parameters of interest determined as an @Risk function. Thus, users can view the randomly generated values for all of the unacceptable outcomes to see if any factor tended to be responsible for a significant number of these cases. For example, if a large percentage of the cases in which surplus falls below a minimum standard involved a high level of catastrophe losses, then the company may be able to reduce catastrophe exposure by revising its reinsurance arrangements or shifting its geographic distribution. Management could use the DFA model to test the effects these changes would have on the results by re-running the model with the revised input before deciding whether these approaches should be adopted.

The basic operation of the model is to generate insurance company cash flows and then evaluate the effect of these cash flows. The model integrates the cash flows from investments and underwriting, including catastrophes and taxes. The model consists of six different inter-related modules: underwriting, investments, catastrophes, taxation, an interest rate generator, and a payment pattern generator. Values generated in one module are shared with the other modules in subsequent calculations.

This paper focuses on an application of DFA. In order to obtain a fuller understanding of DFA modeling, including the limitations of this approach, readers should refer to additional sources. Some useful sources are: D'Arcy, Gorrivett, et. al. (1997), D'Arcy, Gorrivett, Herbers and Hettinger (1997), CAS Committee on Valuation and Financial Analysis (1995), CAS DFA Handbook (1996) and the multi-part Actuarial Review series "How DFA Can Help the Property-Casualty Industry" (1996-1998).

The Test Company

The company used to test this model is a mid-sized property-liability insurer that operates nationwide. The major lines are private passenger and commercial automobile, commercial multi-peril, workers compensation and homeowners. The company has standard reinsurance contracts: excess of loss, quota share and catastrophe coverage. Since the company has been in operation for more than twenty years, enough historical information is available to generate loss payout triangles, frequency and severity trends, loss ratios by age of business, and the other input required for the DFA model.¹

Once the company's data were received, they were input into Dynamo2. Results from the model were generated, and incorporated in a report which was transmitted to the company. That report is included as an Appendix to this paper -- in order to follow the progression of this project, the reader is advised to read the Appendix at this point. This initial report served as the basis for discussions on DFA at a meeting between the authors of this paper and representatives from the company; company personnel involved in these discussions included actuaries, investment personnel, and business planning staff. This report provides both an introduction to DFA and a starting point for a detailed dynamic financial analysis of the firm. The questions raised at that meeting will be covered later in this paper, after a detailed explanation of this DFA model.

The Model

The DFA model used in this paper starts with detailed underwriting and financial data showing the historical and current positions of the company, randomly selects values for 4,387 (!) stochastic variables, calculates the effect on the company of each of these selected values, and then produces summary financial statements of the company for the next five years based on the combined effect of the random variables and other deterministic factors. All this represents a single iteration of the model. The model is set up to run multiple iterations of the model and analyze the distribution of the various outcomes.

Interest Rate Generator

The primary driver of this DFA model is the interest rate generator. Extensive work has been done in finance to develop sophisticated interest rate models. The interested reader is referred to Chan, Karolyi, Longstaff and Sanders (1992) and Hull (1997) for detailed descriptions of some of these models. In this DFA model, a relatively simple (in comparison with other interest rate models) single factor interest rate model is used, one derived by Cox, Ingersoll, and

¹ Generating and gathering the data needed to run this model required the efforts of many people at the company, including the Chief Financial Officer, the Chief Investment Officer and the Chief Actuary, as well as members of their staff. We are very grateful for their cooperation and willingness to supply us with their data; without their help, this paper could not have been written.

Ross (1985) (hereafter referred to as CIR). This simpler interest rate model was selected for two primary reasons. First, property-liability insurers are generally less exposed to interest rate risk than life insurers and banks, two industries for which much of the complex interest rate modeling has been performed. Thus, it is not quite as critical for property-liability insurers that interest rates be modeled as precisely. Second, and more importantly, it is vital that the users of the model fully understand the various components of the model. Actuaries are generally not very familiar with the terminology and approaches of interest rate modeling. Thus, beginning with a relatively straightforward interest rate model should allow the users to become more comfortable with the DFA model relatively quickly. Later, more sophisticated interest rate models can be incorporated and evaluated.

The CIR model describes the short term interest rate as a mean-reverting stochastic process. The CIR interest rate model was originally developed in a continuous-time framework; in that environment, the process dr for the instantaneous change in the level of the short-term risk-free interest rate is characterized by the equation

$$dr = \kappa(\theta - r)dt + \sigma\sqrt{r}dz$$

where θ = the long-run mean to which the interest rate reverts,

κ = the speed of reversion of the interest rate to its long-run mean,

r = the current (instantaneous) short-term interest rate,

σ = the volatility of the interest rate process (as expressed by the standard deviation), and

dz = a standard Wiener process (essentially, a random walk).

For purposes of this DFA model, a discrete-time version of this model is required. According to Cox, Ingersoll, and Ross (1985), the short-term interest rate, in discrete-time, follows a (non-central) chi-squared distribution with degrees of freedom and non-centrality parameters being a function of the κ , θ , and σ parameters above. However, in this DFA model, we approximate the discrete-time form of the CIR model using the following formula:

$$\Delta r = a(b-r)\Delta t + s\sqrt{r} \epsilon$$

where Δr = the discrete-time (annual) change in the short-term interest rate,

Δt = the discrete time interval (one year), and

ϵ = a random sampling from a standard normal distribution.

The CIR model separates interest rate changes into two components, one deterministic component, $a(b-r)$, and one stochastic component, $s\sqrt{r}\epsilon$. The deterministic component moves the current interest rate part way (represented by a) back toward the long term mean b . The further the current interest rate is from this long term mean, the greater the deterministic component of the interest rate movement. The stochastic component causes the interest rate to

jump around this otherwise level trend back toward the mean. Since the stochastic component is multiplied by the square root of the current interest rate, when interest rates are low, the stochastic component is small. This reduces the likelihood that interest rates will become negative. (In the continuous time application of this model, interest rates cannot become negative because if the interest rate were ever to become zero, which a continuous line must cross before becoming negative, then the interest rate will have no stochastic component and will simply be pulled back toward the long term mean (it will actually become $a(\mathbf{b}-r)$). However, in the discrete approximation of this model, negative interest rates can occasionally occur.)

In this interest rate model, the current interest rate is the actual short-term interest rate in the economy at the time the model is run. As of mid-March, 1998, 3 month Treasury bills, a common proxy for short term rates, were yielding 4.985%. Thus, in this model, $r(\mathbf{0})$ is set to 5%. The long-run mean, \mathbf{b} , is also set at 5%. (Empirical tests of the CIR model on historical data indicate a value for the long-run mean of approximately 8%. These tests are based largely on data from the 1980s. When \mathbf{b} is set at 8% in this model, any investment strategy based on long-term bonds tends to under-perform a shorter-term portfolio, since interest rates would tend to move upward, depressing bond prices. To avoid introducing this bias, the long term mean was selected to be the same as the initial value of the short term interest rate. However, this is a variable that can, and should, be altered by the user to reflect individual views of interest rate movements, and to test the sensitivity of results to this variable.)

Since, under the above parameter value selections, the value of $\mathbf{b}-r(\mathbf{0})$ is zero, the deterministic component of the interest rate change is zero in the first year. The stochastic component, then, determines the entire interest rate change. In one run of the model, the value of ϵ in the first year was randomly selected by the model to be -1.00945. Thus, the calculation for the change in interest rates in that model run was:

$$\Delta r = s\sqrt{r} \epsilon = (0.0854)(\sqrt{0.05})(-1.00945) = -0.0193$$

Since the interest rate started at 0.05, the change of -0.0193 led to a new short-term interest rate of 0.0307, or 3.07%.

Once selected, the short term interest rate is used to generate the term structure of interest rates. Based on the interest rate model parameters selected, and upon the simulated short-term interest rate, rates on zero-coupon Treasury bonds are generated for each annual duration up to thirty years. This Treasury term structure is used to determine the market value of the company's bond holdings. The specific equations used to generate the term structure are taken from Cox, Ingersoll, and Ross (1985):

$$R(r,t,T) = \frac{rB(t,T) - \ln A(t,T)}{T - t}$$

where R is the yield-to-maturity at time t on a discount bond that matures at time T , and

$$A(t,T) = \left[\frac{2\gamma e^{[(\kappa+\lambda+\gamma)(T-t)]/2}}{(\kappa+\lambda+\gamma)(e^{\gamma(T-t)}-1)+2\gamma} \right]^{2\kappa\theta/\sigma^2}$$

$$B(t,T) = \frac{2(e^{\gamma(T-t)} - 1)}{(\kappa+\lambda+\gamma)(e^{\gamma(T-t)}-1)+2\gamma}$$

$$\gamma \equiv ((\kappa+\lambda)^2+2\sigma^2)^{1/2}$$

The short-term interest rate is also used to determine the general inflation rate, based on the following formula:

$$I_{CPI} = a + br + s\epsilon$$

where I_{CPI} is the general inflation rate,
 a is a constant (set equal to 0),
 b is a constant (set equal to .725),
 r is the short term interest rate,
 s is the standard deviation of the residuals (here 0.025), and
 ϵ is a random sampling from the standard normal distribution.

The parameter values specified above were derived from regressions on the historical relationships between short-term interest rates and the consumer price index. Continuing the sample case illustrated above for the interest rate (3.07%), the value for $s\epsilon$ in one model run was randomly selected as -0.00459. Thus, the general inflation rate for this year was calculated as

$$I_{CPI} = 0.725(0.0307) - 0.00459 = 0.0177$$

The inflation rate for each line of business is then calculated based on the simulated general inflation rate, according to the following formula:

$$I_{LOB} = a + b I_{CPI} + s \epsilon$$

where I_{LOB} is the line of business specific inflation rate,
 a is a constant that varies by line,
 b is a constant that varies by line,
 I_{CPI} is the general inflation rate,
 s is the standard deviation of the residuals, and
 ϵ is a random sampling from the standard normal distribution.

The parameter values used to determine the line of business inflation rates in the DFA model are shown in the following table, along with a continuation of the sample model run described above, in which the short-term interest rate was 3.07% and the general inflation rate 1.77%. The parameter values were derived from regressions on the historical relationships between the consumer price index and line of business claims inflation rates.

Line of Business	Assumed Inflation in Payment Pattern	a	b	s	Sample Line of Business Inflation
Homeowners	0.052	0.032	.54	.0173	.037
PP Auto - Liability	0.067	0.047	.55	.0194	.060
PP Auto - Phys Dam	0.043	0.011	.88	.0307	.016
Comm Auto - Phys Dam	0.043	0.011	.88	.0307	.053
Comm Auto - Liab	0.067	0.047	.55	.0194	.074
CMP - Liab.	0.045	0.025	.55	.0147	.049
CMP - Prop.	0.045	0.025	.55	.0147	.028
Other Liab.	0.073	0.058	.40	.0206	.061
Other Liab. - Umbrella	0.073	0.058	.40	.0206	.101
WC	0.068	0.047	.58	.0250	.075

The line of business inflation rates are used for two purposes. First, they affect loss development. The initial loss reserves presume a specific inflation rate; the values selected for this run are listed on the above table. To the extent that the calculated line of business inflation rate differs from this value, loss payments will diverge from the initial loss reserves.

The second effect of the line of business inflation rates is on loss severity, which drives the need for future rate increases. In the present application of this model for this specific

company, frequency was assumed to be stable, so the only factor that affects the projected pure premium is the severity trend. Thus, the line of business inflation rate determines the indicated rate level change.

Jurisdictional Risk

Each state poses unique advantages and disadvantages to the operation of an insurance company. Those advantages and disadvantages may take the form of judicial, legislative, or regulatory risk. For example, the likelihood of retroactive workers compensation benefit increases, mandated premium rebates, generous (for the policyholder) interpretations of contract provisions, and the ability to obtain rate increases all vary by state.

In this model, jurisdiction risk is reflected in two ways. First, each state has a range of “acceptable” rate changes -- that is, there is associated with each state a range of rate changes that can be implemented without extraordinary company cost (in terms of time or money) and/or additional insurance department scrutiny. Generally, these ranges limit rate increases more than they do rate decreases, and the ranges are smaller in states with more restrictive regulation. The obvious effect of strict rate regulation is to prevent insurers from increasing rates to the degree they feel is necessary. However, a side effect of capping rate increases is to make companies more reluctant to lower rates as much as would be otherwise indicated if pure premiums are improving.

The other effect of jurisdictional risk is to introduce a lag in implementing indicated rate changes. This lag, shown in the model in terms of years, is longer in states with restrictive rate regulation. The lags indicated on the jurisdictional risk exhibit included in the Appendix are estimated averages for rate increases and decreases; the average lags in the model are multiplied by 1.50 for rate increases and by 0.50 for rate decreases.

The jurisdictional risk parameters are based on a Conning & Company study that ranks all states with respect to regulatory restrictiveness. States ranked as most restrictive were assigned the lowest acceptable rate ranges and the longest lags. The actual values were selected primarily based on the judgement of individuals with experience with rate filings in those states.

As an example of jurisdictional risk in this DFA model, the range of Homeowners rate changes in Massachusetts is from .85 to 1.06 (rates could be lowered by 15% or increased by 6% without significant additional company cost or regulatory scrutiny). Since the average lag is estimated to be ½ year, it would take 3 months to implement a decrease and 9 months to implement an increase. The company’s distribution of writings countrywide is used to determine the overall impact of jurisdictional risk.

Aging Phenomenon

The model reflects the aging phenomenon by separating writings for each line of business into new business, first renewals, and then second and subsequent renewals. Under the aging phenomenon, loss ratios gradually decline with the length of time the policies have been in force with the company. For more details on this experience, see Woll (1987), D’Arcy and Doherty (1989), D’Arcy and Doherty (1990) and Feldblum (1996). One requirement that this approach

introduces is the need for the company to supply exposures and losses broken down by age of the business. Although this allocation is not needed for any statutory or accounting reports, many firms maintain this information for internal reports, although not necessarily in the detail required for the DFA model. In this case, estimates of the loss frequency and severity by age of business can be tried and the resulting loss ratio indications checked for reasonableness, before finalizing these values. The overall result is that new business should have the highest loss ratio, first renewal business should have a slightly lower loss ratio, and the remainder (second and subsequent renewals) should have the lowest loss ratio. Based on data published in D'Arcy and Doherty (1990), the loss ratio on new business ranged from 8 to 42 percentage points above the loss ratio on second and subsequent renewals.

In the model, the distribution of exposures by renewal category is determined as follows. For each line of business, renewal ratios are input that show what percentage of new, first renewal, and second and subsequent renewal business is renewed in the following year. Each renewal rate is applied to the appropriate business from the prior year to determine how many exposures are renewed. For example, for Homeowners, the new business renewal ratio is 60 percent, the first renewal business renewal ratio is 90 percent, and the second and subsequent renewal business is 95 percent. Thus, 60 percent of the exposures that were new business in 1997 become first renewal business in 1998 and 90 percent of first renewal exposures become second and subsequent renewal business in 1999. Thus, policy renewals are deterministic in this model. Since the company has a target growth rate, the number of new policies written in a given year is simply the number needed to achieve the growth target.

Underwriting Cycles

The premium level at which policies are written depends on the targeted growth rate and the position in the underwriting cycle. The property-liability insurance industry underwriting cycle has been the subject of extensive study and is recognized as being quite complex. In line with the goal of keeping this model as straightforward as possible, especially for this early version, the underwriting cycle is simplified. However, it still reflects the different relationships of growth rates and price levels depending on the position of the cycle.

In this model, the underwriting cycle, which can vary /by line, is characterized as being in one of four conditions: mature hard, mature soft, immature hard and immature soft. In a hard market, rates can generally be increased somewhat and growth may still be obtainable. In a soft market, rates generally have to be reduced in order to grow. For each of the four cycle conditions, the probability of moving to another condition in the cycle (e.g., from mature soft to immature hard) is specified as an input. Thus, over the course of the simulation, the company moves through different phases in the underwriting cycle.

In the simulation described in the Appendix, Homeowners is initially in a soft market. Based on the parameters selected, there is a 70 percent chance of remaining in a soft market and a 30 percent chance of moving to an immature hard market in the next year. If the soft market continued and the company wanted to achieve a high growth rate, then the company would have to lower rates, or at least not fully implement any indicated rate increases, in the next year.

Catastrophes

A catastrophe is defined as any natural disaster causing in excess of \$25 million in insured losses. The total number of catastrophes countrywide is simulated based on a Poisson distribution, and then assigned to a “focal point” state based on historical catastrophe experience. The size of each catastrophe is then simulated based on a lognormal distribution, the parameters of which vary according to the identity of the focal point state. For each simulated catastrophe, the contagion effect of the catastrophic losses from the focal point to other states, and by property line of business, is determined based on historical relationships. Finally, the effect of these catastrophes on the company is determined by the market share of the company in each state, by line of business.

For example, in Florida the probability of any number of catastrophes occurring is determined based on a Poisson distribution with a mean of 0.6667. This value, relative to the parameters for all other states, determines the likelihood of a catastrophe being assigned to Florida. For each simulated catastrophe, the size is then determined based on the lognormal distribution with a mean parameter of 2.7697 (in millions) and a variance parameter of 1.1563. For each catastrophe in which Florida is the focal point, 86 percent of the loss is assumed to be incurred in Florida, with the remaining 14 percent distributed to nearby states. All of these parameters were calculated based on data from Property Claim Services over the period 1949-1995. As an example, in one iteration of the model, no catastrophes occurred in Florida in 4 of the 5 years simulated; in the fifth year (2001), two catastrophes occurred, one causing \$143 million in insured losses and the other \$269 million in losses.

It should be noted that the catastrophe module in this DFA model is meant to produce reasonable estimates, and is not intended to replace the more rigorous catastrophe models that are available. In fact, it is possible that the results from other commercially available catastrophe packages could be used in this DFA model.

Investment Results

Investment results for both fixed income securities and equities are determined in the investment module. For bonds, both the statutory value and the market values are calculated for each category of bond (Government, corporate, municipal) and for each maturity segment indicated in the Annual Statement (e.g., one year or less, one to five years, etc.). The market value is determined based on the term structure of interest rates obtained in the interest rate generator module. The cash flows on bonds consider interest rates, coupon rates and default rates, generated stochastically based on historical patterns.

The market value of equities is determined from a simulation based on the Capital Asset Pricing Model. The rate of return on equities is determined in a two step approach. The initial expected market return is the risk free rate, as obtained in the interest rate generator, plus a market risk premium of 8.5% (historical average for 1926-1996). The adjusted market return is the initial expected return minus 4 times the simulated change in the short term interest rate. A random component based on a normal distribution with a mean of 0 and a standard deviation of 15 percent is generated and added to the adjusted market return to determine the overall market

return for each year. The return for the company is then determined by applying the equity beta, which is an input value.

Collecting Data

One decision that needs to be made is how to deal with multiple companies operating under the same management. Many insurers have subsidiaries, but operations are coordinated within the group. In this case, the model should be run on the group as a whole, rather than for each individual company. However, if more detail is needed, then each company can be modeled separately.

The primary source of input data for the model is the Annual Statement. However, additional information is also necessary, which requires the company to provide, or generate, some internal management reports. In addition, the company needs to provide information about exposure growth anticipated, by line for the next five years, and any shift in investment allocations that are contemplated.

Examples of the specific data requirements are illustrated on the exhibits included in the Appendix. In a typical application of this model, some of the more problematic data areas might potentially include exposures and rates by renewal category, historic loss ratios by renewal category, and various aggregation issues (the trade-off between data volume and its homogeneity when examining lines and types of business). Also, in order to generate more credible cash flows, or to deal with homogeneous data, Annual Statement lines of business can be aggregated or split into separate components, as needed.

Running the Model

The first step in running the model (after the company-specific data has been input) is to determine where the industry stands in the underwriting cycle for each line of business. It is presumed that the insurance industry follows a time dependent cycle of competitiveness. In a soft market, premium increases tend to significantly reduce market share. Conversely in a hard market, policyholders find it difficult to obtain insurance, so it is easier for an insurer to increase market share.

The next step is to determine the number of iterations to be run. The higher the number of iterations, the more stable the distribution of outcomes is likely to be, but the program will take correspondingly longer to run. As a word of advice, when beginning to learn the program, this number should be kept small (5-10) to minimize the time needed to complete the run. Frequently, it will be apparent from even that limited output that something is amiss. After adjusting the input data and the parameters until the user feels confident that they are reasonable, a larger number of iterations (e.g., 1,000 or more) should be run to obtain the full benefit of the DFA model.

At this point, reasonability checks should be performed to make sure the input values are

realistic. One check is to multiply frequency by severity and divide the product by the average premium, for each age of business, to see if the implied loss ratios had the appropriate relationship (new business highest, second and subsequent renewal the lowest). Another check is that the average catastrophe losses are within expected bounds.

The next step is to determine exactly what output is desired. Any value that appears in the sections of the model where calculations are performed, or any parameter generated by the model, is a potential output value. Premiums, surplus, loss and operating ratios, investment returns, catastrophe losses, interest rates, inflation rates, and regulatory ratios are all potentially useful output values. In some cases additional detail might be desired. For example, the loss ratio by line, by year and by age of business, direct, ceded, or net, could all be listed as output variables. To determine the cause of a potentially high loss ratio, the frequencies, severities, number of exposures and average premiums could also be listed. However, at some point the magnitude of the output data could become unmanageable. Since the model provides for ten lines of business forecasted for the next five years, and exposures are maintained for new business, first renewals, and second and subsequent renewals, if each value were shown for direct, ceded and net values, there would be 450 loss ratios (plus frequencies, severities, and exposures) for each iteration. Finding the cause of any adverse indications would be a major chore. Thus, care needs to be exercised to keep the output manageable, especially when the model is being fine-tuned. The exhibits included in the Appendix are indicative of the types of output that can be helpful.

Changing the Model's Parameters

Since the DFA model is built in a spreadsheet environment, changing the model's parameters is straightforward. The user merely needs to know which input screen contains the key variables. The following table lists some of these key variables, and their locations in the spreadsheet model.

<u>Variable</u>	<u>Description</u>	<u>Sheet Location</u>	<u>Cell Reference</u>
U/W Cycle Position	Users viewpoint on current market conditions.	General Input	C6 to C15
Growth Rates	Expected growth rates in exposures	Premium Input	Row 22
Renewal Ratio		Premium Input	Rows 30-32
Expense Provisions	Commissions, General, Other Acq., Taxes, Dividends, and Nonrecurring Expenses	Premium Input	Rows 42, 46, 50, 54, 57, 59
Q/S Ceding Commission		Premium Input	Row 62

Exposure Changes	Use to Change Exposures and Market Shares by State	Exposure Input	
Selected 1997 Severities		Loss Input	Rows 167 to 169
Selected 1997 Frequencies		Loss Input	Rows 196 to 198
Selected ULAE Provisions		Loss Input	Rows 227 to 233
Q/S Arrangements		Loss Input	Rows 255-259
XOL Arrangements	Includes Attachment Points and Cost of Reinsurance	Loss Input	Rows 268 to 297
Stop Loss Arrangements	Includes Attachment Points and Cost of Reinsurance	Loss Input	Rows 349 to 353
Cat. Re Arrangements	Includes Attachment Points and Cost of Reinsurance	Loss Input	Rows 359 to 363
Stock Betas		Investment Input	Rows 95 to 98
Capital Infusions		Investment Input	Rows 86 to 91
Reinvestment Allocations	How Investment Income is Reinvested	Investment Input	Rows 109 to 125
Long-Run Interest Rate		Interest Generator	C27
Current Interest Rate		Interest Generator	C29
General Inflation Parameters		Interest Generator	C35 to C37
LOB Inflation Parameters		Interest Generator	Rows 54 to 56
U/W Cycle Parameters	Includes Probability of Changing Market Condition and Supply/Demand Curves	U/W Cycle Generator	C7 to H34

Initial Reaction of the Company to the DFA Report

First Impressions

The company's first direct exposure to the DFA model occurred at a meeting between the authors and representatives of the company's actuarial, investment, and business planning departments. At this time the report included in the Appendix was delivered and a detailed explanation of the DFA model was presented. Many questions were raised at that point, a majority of which related to asking for an explanation of how the model worked. However, there were also a number of questions that will lead to model improvements and enhancements. Overall, company personnel were enthusiastic about the model and have hopes of using it in the

future for strategic planning purposes. They also saw it as a tool to help the different divisions of the company -- actuarial, financial, investment, and planning -- work together. Finally, the company liked the software platform on which the DFA model is based. The Excel spreadsheet format makes the model user-friendly and simple to change and enhance, and allows the user to examine the inner workings of the model in a non-black box environment.

Concerns

The company expressed certain concerns regarding the model and the results that were initially supplied to them. It was evident that the **Base Case** indications were unacceptable (primarily due to the high growth goals of the company); however, the managers felt that constraining growth was not a viable alternative. Other options were explored, including increasing the new business renewal rate. For Homeowners this value was 60 percent. Raising it to 80-90 percent caused some improvement, but not enough to turn results around completely. Another change was to modify the maximum ceded under the aggregate reinsurance contract. This also had a favorable effect on forecasted results.

In order to gain a better understanding of what was causing the results, two additional values, the short term interest rate and catastrophe losses, were added to the output page and the simulation re-run during the meeting. The ability to modify the model and quickly see the impact of the changes was viewed very favorably.

Some of the questions raised indicated the need for enhancements in future versions of the model. One question related to prepayments on bonds and CMOs as a function of interest rate changes. Another wanted to examine the effect of changing growth patterns by state, to examine the effect on the company of growing in a particular area, in this case a high catastrophic-risk state.

The company would like to use a DFA model for capital allocation. The current model examines the riskiness of the company as a whole. It was suggested that separate runs could be performed for separate business segments (commercial/personal lines or by regions) in order to determine capital needs.

Another question related to the ability to plug in output from sophisticated fixed income security and catastrophe software into the DFA model. When Dynamo2 was originally designed, it was anticipated that many users would have access to different catastrophe models and might want to use those instead of the catastrophe module built in to this model. It is apparent from this question that similar issues relate to the investment modules.

Several questions related to the investment allocation. Currently the investment allocation applies to new money. If the cash flow requires assets to be sold, this is done proportionally. The investment managers would like to be able to reallocate the entire investment portfolio and indicate which assets should be sold, if necessary.

Another issue raised was the ability to focus on the difference between the expected values indicated by running the model and actual results. Managers wanted to be able to see why results differed from what was projected, so that they could better understand what they did right if a year was better than projected, or what went wrong if actual results were worse than expected. This DFA model allows this to occur, but requires the user to retain detailed output from the projections.

In examining the DFA runs, many questions were raised about what might have been causing adverse experience. It was suggested that the program be revised to capture detailed financial data on any simulation where surplus fell below a certain level. Thus, the managers could look at what caused the problems in order to better avoid them.

Applications

In addition to expressing the desire to use the DFA model for capital allocation purposes, the company also discussed the possibility of using the model to look at other companies. This might allow them to gain insights into their competitive position in the industry. The company also sees the model as a significant strategic planning tool -- for example, in evaluating how growth in one particular state affects the overall company. Another use was in reinsurance contract negotiations, where the expected effect of different limits or other contract terms could be evaluated. Finally, the CFO of the company expressed an interest in using the model, not only internally, but also in external communications. The investment community was specifically mentioned in this regard, but other possibilities also include regulators, rating agencies, and reinsurers.

Variable Adjustments

During the presentation, several different computers loaded with the DFA model were available, allowing the managers to break into groups and test different DFA scenarios. For example, one group of managers adjusted the interest rate parameters. Specifically, they raised the long-run mean interest rate level to 10 percent and reduced the volatility parameter to 0, to observe the effect of increasing interest rates for a small sample of runs. Other groups ran the model after adjusting one or more of exposures, losses, the reinsurance program, catastrophe parameters, exposure growth assumptions, and investment variables. In still other cases, certain stochastic variables were "shut off" -- e.g., by setting the volatility parameter of the variable equal to zero. This allowed the user the opportunity to see the impact of certain stochastic variables without introducing additional "noise" from those variables that were turned off.

In general, this exercise was seen as beneficial by all the groups, not just the actuaries. Having a viable DFA model will serve to help the different areas of the company work more closely together, and facilitate coordinating the efforts of the various areas.

Presentation to Upper Management

Members of the group raised several questions about how this model should be presented to the upper management of the company. In addition to needing to get comfortable with the model, they also wanted to be able to focus on how actual results differed from the projections. To do this, it was suggested that they might use the model to project results for last year (run the model without including data for the latest year and then compare the actual results with the output from the model). In addition, they wanted to print out key financial exhibits for the situations that were unacceptable, so that they could focus on what went wrong in those cases. This feature is available in the @Risk version of the model, but currently not in the Excel version.

Examining the effect of a company's use of a DFA model is a long term prospect.

Modifications and enhancements to the model would be expected, as the company asks new questions after seeing initial indications. While it is too early to provide any information about the final effect of this process, the initial meeting and response suggest that the DFA model will provide a very useful management tool.

Future Enhancements

Enhancement of the public-access DFA model is an on-going process. Input and suggestions from users and other interested parties are welcomed and encouraged. The following items represent some of the enhancements to the model which are currently being considered.

- Determine the impact of callability provisions and other options embedded in insurer bond holdings. This will require identification of those bonds in the insurer's portfolio that have such options, information regarding when during the life of the bond the option is exercisable, and the call premium or other parameters associated with the embedded option. The valuation framework already incorporated within the DFA model -- i.e., market valuation of fixed-income securities based on the simulated term structure of interest rates -- will form the basis for the endogenous decision whether or not to exercise the option.
- Explicitly value mortgage-backed securities. These securities are comprising ever-larger proportions of insurer portfolios. In particular, for example, the prepayment risk associated with collateralized mortgage obligations will be simulated using the Public Securities Association (PSA) model of monthly prepayments on residential mortgages, with the parameters of the PSA model being impacted by simulated general economic conditions.
- Add state and/or regional detail in the underwriting module to facilitate measuring the effect of, for example, a change in the growth rate for a particular state.
- Continue to develop the underwriting cycle module and the associated demand curves, including their impact on business retention rates and jurisdictional risk.
- Implement correlations for the frequency and severity figures for business of different ages within a given line and between lines of business.
- Add tax-loss carry-forwards and carry-backs to the tax module.
- Add a module which produces risk-based capital results.

Conclusion

DFA is becoming an important concept for property-liability insurers, and it is likely that actuaries will be called upon to participate in, if not lead, this endeavor. This paper describes one DFA model. This model is publicly available and its use is encouraged, and comments on its effectiveness, limitations and potential improvements are actively solicited. While DFA for property-liability insurers is in a nascent stage, the initial reaction of company management to the application of this model to their operations was very favorable and provided evidence that DFA

will prove valuable to the industry.

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Application of a Dynamic Financial Analysis Model to the Test Company: Report to Management

Introduction

The purpose of this report is to describe and explain a Dynamic Financial Analysis (DFA) model that represents a new management tool for insurance companies. The attached exhibits should be viewed as illustrative examples of output from running this model. These results are **not** a full blown dynamic financial analysis of the company, but represent a starting point for performing an analysis.

DFA, in essence, represents an enhanced approach to the traditional planning function undertaken by insurance companies. It provides a far more effective tool for forecasting future financial and operating conditions of an insurance company than prior methods for two primary reasons. First, the interactions between the underwriting and investment sides of the insurance business are formally integrated. Second, this approach utilizes advances in computer technology and modeling techniques to provide almost instantaneous feedback to decision makers, allowing for the evaluation of numerous operating alternatives.

The specific innovations to the planning process that are incorporated in DFA modeling are:

- 1) DFA provides a probability distribution of likely outcomes, rather than a single expected value forecast
- 2) DFA incorporates the correlations among lines of business, between loss reserve adequacy and rate adequacy, and between the investment and underwriting sides of insurance operations
- 3) by utilizing the technology of personal computers and common software, DFA models can be run by the users many times with different assumptions and different parameters, in order to see the effect that changes in the model or in operations can have on the results

Caveats

Although the output generated by a DFA model can look impressive, with detailed exhibits indicating the expected results for years into the future, and other exhibits indicating the probabilities of financial distress, the user must keep in mind that the output is only as good as the model and the underlying assumptions. DFA modeling has several specific limitations. First, models are simplified representations of reality. Models must be simplified in order to be useful; if all the factors that could possibly affect an insurer were included in a model, then it would just be too complex to be a useful model. When developing a model, the most relevant factors at that

time are included. However, if conditions were to change markedly, which is entirely possible, then other factors that were omitted from the model could become important, affecting the accuracy of the results of the model. For example, during the 1920s, insurance profit margins were established that effectively ignored investment income. At this time interest rates were low (1-2%) and most business was in the short-tailed property lines. However, by the 1960s, interest rates were much higher and long-tailed lines accounted for almost 2/3rds of written premiums. Thus, it was no longer feasible to ignore the effect of interest rates on underwriting profit margins.

Second, some factors are important, but because they are beyond the scope of an actuarial analysis, they are omitted from the model. For example, fraud by managers is a leading cause of insurance insolvency. However, all insurers are not equally exposed to fraudulent behavior. Whether fraud is likely to occur (or is currently occurring) at a particular insurer, is not something an actuary is qualified to ascertain. Thus, any financial effects from fraudulent behavior are simply omitted from the model. Other examples of omitted factors that definitely could have a significant effect on insurance operations include a change in the tax code, repeal of the McCarran-Ferguson Act, a major shift in the application of a legal doctrine or the risk of a line of business being socialized by a state, province or federal government. Thus, the range of possible outcomes from operating an insurance company is actually greater than a DFA model would indicate; the model is designed to account only for risks that can be realistically quantified.

Finally, the values used as input in the model are derived from past experience and current operational plans. To the extent that something happens in the future that is completely out of line with past events, the model will be inaccurate. For example, the size of a specific catastrophe is based on a lognormal distribution with the parameter values based on experience over the period 1949-1995 (adjusted for inflation). However, if this process had been used just prior to 1992, the chance of two events occurring within the next 2 ½ years, both of which exceeded the largest previous loss by a factor of more than 2, would have been extremely small. However, Hurricane Andrew caused \$15.5 billion in losses in August 1992 and the Northridge earthquake caused \$12.5 billion in insured losses in January 1994. The largest insured loss prior to that was Hurricane Hugo, which had caused \$4.2 billion in losses in 1989. Also, if changes in any operations occur, then the results would not be valid. Thus, the proper use of a DFA model is to continue to update the model as conditions or operations change.

With these caveats in mind, let's proceed to a description of the DFA model.

Dynamo2

The specific DFA model that is applied to the company's financial data is termed **Dynamo2**, which is a public access DFA model developed by the actuarial consulting firm Miller, Rapp, Herbers & Terry, Inc. This model is designed to be run on personal computers with Microsoft Excel and @Risk, two widely available software programs. The model operates by running a large number of iterations, with each iteration representing a single possible outcome. Each iteration, in turn, reflects the results of hundreds of different, but sometimes correlated, random factors that affect different parts of the insurer's operations. Selected values from each simulation are stored and used to calculate the mean and the distribution of the indicated results.

The model consists of several different modules, each of which calculates a component of the model indications. Separate modules are included for investments, catastrophes, underwriting, taxation, the interest rate generator and loss reserve development. The model allows for ten different lines of business:

- Homeowners
- Private Passenger Auto Liability
- Private Passenger Auto Physical Damages
- Commercial Auto Liability
- Commercial Auto Physical Damage
- Commercial Multi-Peril - Liability (which includes Professional Liability)
- Commercial Multi-Peril - Property (including Special Property)
- Other Liability
- Other Liability - Umbrella
- Workers Compensation

For each line of business, the underwriting gain or loss is calculated separately for: 1) new business, 2) 1st renewal business and 3) 2nd and subsequent renewals. This division is provided to reflect the aging phenomenon, in which loss experience improves with the length of time a policyholder has been with a company. These three categories are then added to calculate underwriting results on a direct, ceded and net basis.

The values for each simulation are shared among the different modules. Thus, if the random number generator produces a high value for the short term interest rate, this high interest rate is used in the investment module as well as the underwriting module. Similarly, a high value for catastrophes in the catastrophe module carries through to the reinsurance and underwriting modules.

The primary risks that are reflected in the model are:

- 1) Pricing risk
- 2) Loss reserve development risk
- 3) Catastrophe risk
- 4) Investment risk

Pricing risk is composed of a number of interrelated components. First, loss frequency and severity are both subject to random variation. Second, inflation affects loss severity. This effect is correlated with the short term interest rate, and is line of business specific. The indicated rate level change depends on the relationship between the current premiums and the premium indicated by inflationary impact on loss severity by line. However, jurisdictional risk (which is state specific) affects the ability of an insurer to make rate changes. Jurisdictional risk is reflected in both a range of allowable rate changes (lower increases would be allowed in jurisdictions with stringent regulation) and the time lag for incorporating new rates (it would take

longer to raise rates in a state with restrictive regulation).

Finally, pricing risk is subject to the underwriting cycle. The underwriting cycle is simplified to be represented by four distinct phases: mature hard market (price increases can be taken with a minimal effect on market share), mature soft market (price increases significantly reduce market share), immature hard market (the market is starting to harden) and immature soft market (the market is beginning to soften). For each phase, the supply/demand function for insurance is different. Also, for each phase, there is a different probability distribution that represents the chance of remaining in that stage or of moving to another stage for the next year.

The loss reserves input into the model should be the reserves indicated based on an actuarial analysis of loss development, not necessarily the carried reserves. For this project, we relied on the reserve analysis performed by the company without independent audit, review or verification. Assuming the reserve levels are accurate, the expected reserve development would be zero. However, reserve development is still subject to random variation and to inflation. The indicated loss reserves contain an implied inflation factor. To the extent that inflation differs from this level, there will be a systematic effect on reserve development. Even if inflation were to occur at the expected level, then remaining random errors will affect the development.

Catastrophe risk is included in the model by the use of a two step approach. A poisson distribution is used to generate the number of catastrophes (of all types) that occur in a given year. Then, each catastrophe that occurs is assigned, based on historical patterns, to a specific geographical area (one state that is the primary focus of the loss). Next, the size of each catastrophe is determined based on a lognormal distribution, with the parameters determined based on the primary state in which the loss occurs. Finally, the contagion effect of the loss on other states, again based on historical patterns, is determined so that the total catastrophe loss for the year in each state can be determined. The amount of each loss that is ceded is determined based on the company's catastrophe insurance program, which allows calculation of the direct, ceded and net experience.

The investment risk reflects the combined effect of bonds and stocks. Statutory bond values are determined based on the interest rates in effect when the bond was purchased and the amortization schedule, plus defaults that occur randomly based on historical patterns. Market values of bonds are a function of the current interest rates as simulated. Stock market values are based on the starting values and the randomly generated rates of return. Equity returns are based on simulated changes in interest rates, and include significant random variation, with the parameters determined based on historical rates of return.

Model Input

The model requires extensive financial data as input. Some of the historical data required for input can be obtained from the Annual Statement, but in other cases direct, rather than net, data are preferable, which must be drawn from additional reports. In this case, the input was provided by the company, including reports on direct and net premiums, exposures by line and by age of business, and premium level, loss frequency, loss severity, market share and renewal rates by line. In addition, planned growth by line of business and the user's perception of the phase of the underwriting cycle by line is input. From the Annual Statement the input values include the statutory value of assets and liabilities and the current investment allocations. The expense

provisions were taken from the Insurance Expense Exhibit. Loss development was developed based on direct triangles provided by the company. The company also provided a detailed listing of reinsurance contracts and the beta for equities.

Attached are copies of the data input for this program for the company as a whole and for the Homeowners line of business. This line of business data illustrates the by line information required to run this model. These exhibits include:

- **General Input** - selections for the current market conditions by line
- **Loss Triangle Input** - historical direct paid loss development by line
- **Underwriting Module Input** - new and renewal exposures written and premium levels for the last two years, projected growth rates for the next five years, renewal ratios by age of business and expense factors, all by line of business
- **Exposure Distribution** - current number of exposures written by state, by line and historic exposures written by line
- **Market Share** - market share estimates for property coverage (for catastrophe losses)
- **Loss Development Factor Selection** - the selected paid loss development factors based on the historic loss development patterns (used to generate cash flows)
- **Loss Information Input** - selected ultimate losses and allocated loss adjustment expenses and claim counts, direct and net paid losses and earned premium, loss frequencies and severities (in total and by age of business), unallocated loss adjustment expense factors, and reinsurance treaties, all by line of business
- **Investment Input** - statutory and market values of assets by annual statement category, coupon and dividend rates and equity betas

Model Output

The ability to generate an almost infinite number of reports from a DFA model is both a strength and a weakness of this approach. Care has to be taken to assure that the user is not overwhelmed with information and, therefore, unable to utilize the results of the model in any reasonable manner. Thus, the initial report focuses on a limited number of key variables for an insurer, and indicates the expected values as well as the distribution of outcomes from the model. Also, examples of more detailed reports for a few selected outcomes are shown to illustrate the potential of a DFA model to troubleshoot particular problems that contributed to adverse financial results.

The true benefit of a DFA model is the ability it gives to the decision makers in an insurance company to test out various financial and operating strategies and see what the

indicated effect is on both expected returns and the distribution of results. Unlike the planning process that has previously been used by many insurers, which tended to be done annually or on some other regular schedule, a DFA model can be a regular management tool that can be rerun whenever a major decision needs to be made. Thus, the goal of our first meeting will be to demonstrate the use of this DFA model so that management can decide what values to change.

The output from the DFA model based on the initial input values (as shown on the input exhibits) for a run with 50 iterations using the Excel option are shown in the exhibits marketed **Base Case**. The results for each simulation, and the average values, are shown for statutory surplus, the premium to surplus ratio, the operating ratio and the net loss ratio for all lines combined for each year 1998-2002. In this run, the average value of the surplus over all 50 iterations was \$177 million for 1998, \$173 million for 1999, \$167 million for 2000, \$150 million for 2001 and \$133 million for 2002. Since the simulation included 50 iterations, it is difficult to draw conclusions from the individual results. The distribution of these results for surplus, premium to surplus ratio, operating ratio and loss ratio for the year 2002 are shown in the graphs. These illustrate the distribution of outcomes to allow the user to determine the likelihood of specific outcomes, either bad (surplus below a minimum level, premium to surplus ratio over an acceptable target, etc.) or favorable (operating ratio below a target level).

In addition, detailed data can be analyzed for selected outcomes. For example, the statutory balance sheet, the IRIS test results and the loss ratios on a direct, ceded and net basis by age of business are shown for an example of a single iteration. If desired, even more detailed data (frequency and severity, interest rate level, number, size and distribution of catastrophes, etc.) can be examined. This allows the user to troubleshoot the unfavorable outcomes to determine what strategies would work best to reduce the likelihood of their occurrence.

It is obvious from looking at the average values and the distributions from this initial run that the results are very unfavorable. The statutory surplus declines, on average, and the premium to surplus ratios increase to unacceptable levels. Loss ratios, especially in the latter years of the forecast period, increase to over 75 percent. These indications, while causing concern, are actually exactly what is needed to illustrate the potential benefits of a DFA model. Since the forecasted values are unacceptable, then changes should be made to generate more favorable indications. What changes should be made are up to management, and DFA is the tool to help management access the effect of particular changes.

For example, one cause of the increase in loss ratios is the amount of new business that is written to meet the growth rates initially input into the model. This growth, coupled with relatively low retention rates, requires the company to write a large amount of new business each year, with its corresponding high loss ratios. The **Base Case** model projects exposure growth of 5-10% for all lines of business for the years 2000-2002. This compares with a negative growth forecast for 1998 and low growth, 1-3.5%, for 1999. In this example, detailed loss and exposure results are shown for new Homeowners business so that the effect of rapid growth in exposures can be examined. In an effort to grow at a 10% rate, the number of new Homeowners exposures in 2002 is 16,119. (See the exhibit on New Business for Homeowners) Since the loss ratio on this new business is expected to be 26 percentage points higher than long term business (see last line on this sheet), this high growth imposes a significant penalty on the company.

The effect of reducing these growth rates can be seen in the exhibits marked **Constrained Growth**. The only difference between the initial run and this run is that the growth rates were

held to a maximum of 2 percent per year. The indications are much more favorable in this situation. In this case the average values of surplus are \$176 million, \$177 million, \$183 million, \$192 million and \$203 million, for 1998-2002 respectively. Although the distributions illustrated on the graphs for 2002 still show unacceptable results in some situations, the average values are much more feasible than in the **Base Case**. The effect of constraining the growth can be seen on the New Business for Homeowners exhibit. In this case, the number of new exposures is only 7,177, compared to 16,119 at the 10 percent growth rate.

The output illustrated in the two cases discussed above was based on runs of 50 iterations each using the Excel option. The model also can be run using @Risk, which provides significant additional capabilities. The **Base Case** model was also run using @Risk with 1000 iterations. The numerical values of statutory surplus, displayed both in percentiles and graphically for 1998-2002, are shown as additional exhibits.

What other changes could or should be made? Such items as policy renewal rates, expense provisions, the rate at which premium is earned (which reflects policy term), exposure distribution by state, projected average frequencies and severities by age of business, reinsurance provisions (including attachment points, costs and ceding commissions) and investment provisions (including allocation of new investments, stock betas and surplus additions) can all be easily manipulated and evaluated by the use of this DFA model.

The primary point of this report is that DFA is a management tool. The decision makers in the company should take the initiative in proposing changes and analyzing the effects. The goal of the meeting with the company is to explain and demonstrate the DFA model so that managers can effectively use this tool. Much of the meeting will be devoted to hands-on work with the model so you can evaluate its effectiveness and we can see what works for you and in what ways the model needs to be improved to facilitate its use as a management planning tool.

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