Dynamic Financial Modeling—Issues and Approaches

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Daykin, Pentikainen, and Pesonen (as well as other authors) have described the elements that can comprise a dynamic financial model of a property/casualty insurer and have discussed options for several important elements where different approaches are reasonable. This paper further describes the issues which arise in designing and implementing a dynamic financial model and discusses possible methods of analyzing and interpreting the results of DFA analyses. Implementing such a model raises a number of difficult conceptual and technical issues. In this paper we discuss a number of important model elements and the related implementation issues.

1 Introduction

1.1 Background And Context

Historically, actuaries have opined on the adequacy of loss reserves for insurance companies and self-insuring non-insurance entities. Recently, two concerns have arisen in the actuarial profession. First, opinions regarding loss reserves do not speak fully to the greater issue of solvency. Second, loss reserve opinions are point estimates and do not address the variability which is characteristic of insurance. A technique that could address these two concerns is Dynamic Financial Analysis, where a company's complete operations are modeled and simulated.

Historically, the actuary's role focused on some well-defined technical aspects of a company's operations: pricing products; designing risk classification structures; designing and applying experience rating plans; and estimating loss reserve requirements. As the profession evolved, actuaries were called upon to apply their analytical skills and industry knowledge to a broader array of problems, including claims management, underwriting, and strategic and operations planning.

At the same time that the actuary's role was expanding to encompass these additional problems, regulators became increasingly concerned over their ability to monitor and safeguard insurers' solvency in an increasingly volatile economy and competitive business. Regulators' concerns over more effective solvency monitoring tools led to the implementation of dynamic solvency testing in Canada and risk-based capital solvency monitoring in the United States.

The expansion of the actuary's role, and the continuing development of solvency monitoring tools, have converged under the category of Dynamic Financial Analysis, or DFA. The CAS has defined Dynamic Financial Analysis as:

"... the process by which an actuary analyzes the financial condition of an insurance enterprise. Financial condition refers to the ability of the company's capital and surplus to adequately support the company's future operations through an unknown future environment."[12]

Dynamic Financial Analysis can be a tool which can provide much of the information necessary for insurance company managements, investors, regulators and others with an interest in the insurance business to:

- Evaluate an insurer's financial strength, including the likelihood of insolvency and the economic and operating scenarios which would impair surplus;
- Evaluate and measure an insurer's operating risks;
- Evaluate alternative operating strategies and tactics relative to different management objectives, including maximizing the value of the firm subject to risk constraints;

- Determine the value of an insurer.

The range of these analyses implies the use of different types of data and outcome performance measures.

Given these desired capabilities for DFA, we feel it is appropriate to define DFA, and the models which implement such analyses, as having the following distinguishing characteristics:

- DFA incorporates both the liability and asset processes;
- DFA takes into account the stochastic nature of an insurer's operations;
- DFA treats the company as an ongoing operation, and extends over a time frame defined by the transaction lifetimes of the insurance products involved, although it may also have the flexibility to evaluate a company in run-off.

1.2 Objectives

Our objectives in this paper are:

- To discuss some of the issues which arise in designing and implementing a dynamic financial analysis computer simulation model;
- To suggest possible ways to approach the modeling of some of the more important components of the insurance process;
- To suggest directions and tools for the analysis of the output of a DFA model.

Although we have considered and experimented with many of the concepts discussed in this paper, we have not completed the extensive research necessary to specify all of the interactions that may be included in a DFA model, or to estimate all of the required parameters. We feel, however, that by describing our conception of the interactions and parameters involved in modeling the insurance process, based upon our understanding of the insurance business and the potential uses of DFA, we can assist others in designing, applying, and interpreting the results of DFA models.

The process of defining a valid and useful DFA model will be an iterative process consisting of:

- Hypothesizing relationships among the relevant variables;
- Research to parameterize those relationships;
- Experiments via a series of simulations to analyze the results for reasonableness.

The research phases of this process will produce a better understanding of the insurance process being modeled, such as the mechanics of the competitive market for insurance products or the correlations of experience between lines of business. The experimental phases will test the new understandings produced by research and may also identify and rank the priority of future research efforts.

2 Modeling Insurance

2.1 Introduction

Existing models of insurance range from complex representations which attempt to describe insurance buyers' preferences and decisions as they select among different policies and non-insurance alternatives to preserve and protect their wealth, to relatively straightforward accounting representations of company experience. Where, in this range, is the appropriate level to build a DFA model? What level of detail and specific components should be included in a DFA model?

The business of insurance is complex. When an insurer enters a given product market, it must design and price the product, market it, underwrite the risks who apply for coverage, issue the policies, maintain and service the insureds, and adjust and pay claims as necessary. In addition, the company must manage its business (control its expenses; invest its assets; set reserves; control exposure concentrations; and devise and implement strategic and operating plans). And this list is far from exhaustive!

From this capsule description of the insurance business, it is apparent that its reality is too complex to be replicated in detail in a single model. Parsimony is a desirable feature of any model. One attractive aspect of modeling is precisely the reduction of complex problems to manageable proportions. A model builder therefore usually selects only the salient features of the process to be modeled, based upon hypotheses, prior knowledge of the subject real world process, or existing models of similar processes. By salient features, we mean the features of the real world process which have relatively greater effects on the process outcomes.

In this paper, where one of our objectives is to discuss the issues which arise in the design and implementation of DFA models, we consider details of the insurance process and introduce variables (well beyond what even Tolstoy could consider parsimonious) which might be considered unimportant in other contexts. The importance or unimportance of some of the features mentioned will ultimately only be determined by the implementation and application of actual DFA models incorporating those features.

2.2 The Insurance Process

The insurance process (the interactions of insurance product buyers and sellers in more or less competitive markets) exists because of the existence of insurable risks and the desire of individuals and corporations to reduce the financial effects of those risks. For the purpose of modeling the insurance process we can conceptualize and describe insurable risks in terms of their corresponding insurance products. Each insurance product can be defined according to that product's attributes. In describing these attributes, we again adopt the perspective that a conceptual representation of an insurance product can be quite detailed. We recognize that not all the details dealt with below will be relevant to all DFA analyses, but may indeed be relevant to particular analyses for which DFA techniques are applicable. In our description of each product attribute, we attempt to provide some brief discussion of its relevance in a DFA modeling application.

The product attributes are grouped in terms of:

- Policy characteristics;
- Market characteristics;
- Operational characteristics; and
- Loss characteristics.

2.3 Policy Characteristics

2.3.1 Name

The product name serves as an identifier so that the experience of a particular product can be separated from the output as necessary.

2.3.2 State

The state is that state associated with some, or all, of the principal locational characteristics of the product (exposure location; regulatory jurisdiction; applicable residual market(s), etc.). In the United States, most aspects of the insurance business are regulated at the state level. The state which has regulatory jurisdiction, which is often also the venue of the product sale, and the subject exposure location, is therefore a relevant and convenient descriptor for insurance products from a management viewpoint. One can also associate some of the differences in the competitive environment with the product state.

2.3.3 Territory

The territory identifies the exposure location in terms of its rating or statistical territory as defined by the insurer's operating experience information system's data structure. Insurers commonly identify and price their products according to the corresponding exposure location in terms of its rating or statistical territory. Operating tactics are often defined in terms of product territories. Accurate evaluation of the risk posed by catastrophes typically requires information on the distribution of exposures by location by small geographic units, where territory may be interpreted in terms of the exposure location zip code. The differentiation among products by state and territory may also affect the product pricing and growth or retraction decision rules used in a DFA model.

2.3.4 Annual Statement Line

Because much of the insurer's internal, regulatory, and financial rating bureau reporting and evaluation uses the structure of the Annual Statement, it is necessary to allocate each of the products defined to its appropriate Annual Statement line. In addition, the Annual Statement line descriptor for a product can help define the covered losses for that product and explain the applicability of other product characteristics.

2.3.5 Exposure

Exposure specifies the amount of exposure written by the modeled company. Exposure is well defined for pricing purposes for all lines of business. The exposure bases defined for pricing purposes may not, however, be the most appropriate, or easiest to use, for financial modeling purposes.[13] If this is the case, one can equate exposure to policy counts, insured limits, or another suitable measure.

2.3.6 Price

A dynamic financial model which takes into account competitive market interactions will need to recognize more than one price for a given insurance product in the insurance process.

- Price as a result of the pricing algorithm - A starting point for the determination of the price charged by an insurer in a competitive market is typically a price determined by a formulaic algorithm which usually takes into account past and expected loss, expense, and investment experience and an appropriate profit and contingency load.
- Market price - depending upon current competitive market conditions, the insurer's current strategic plan and objectives, and financial condition, the price actually charged in a competitive market may differ from that indicated by the pricing algorithm.

The distinction, and changing relationship during the simulation period, between these two variables is an important and difficult aspect of designing and implementing a DFA model. There is little research presently available which defines and specifies the interaction between these two variables as market conditions change, yet it is difficult to see how a realistic and meaningful model can be constructed without incorporating this interaction.

2.3.7 Policy Term

The term of the policy coverage for a product has an effect on the (unearned premium and retrospective rating adjustments) reserves held by the company and the rate at which some pricing changes can be reflected in the collected premium levels.

2.3.8 Coverage Terms

Insurers have some flexibility in controlling loss costs by managing policy coverage terms (deductibles, co-payments, limits, coverage wording). Two of the more important coverage limitations are the coverage limit (the maximum amount payable for indemnity under this product) and the coverage deductible (the portion of the direct loss borne by the policyholder). Coverage limitations are a potentially important response to the risks presented by concentrations of exposure subject to catastrophes and therefore may be an important variable in DFA.

2.3.9 Expense Structure

An insurer's expense structure affects both its financial results, and its relative competitive position. The treatment of insurer expenses can recognize both loss adjustment and non-loss adjustment expenses, and different specifications may be appropriate for these two components (fixed and variable, a function of premium and/or loss). Changes over time in both general and/or claim specific inflation can be incorporated in the expense structure.

2.4 Market Characteristics

2.4.1 Operating Environment

The operating results for nominally identical products offered by the same insurer can be materially different depending upon the operating environment in which they are offered. Within the insurance industry, regulatory practices, competition and the corresponding operating environment are commonly perceived to vary significantly by jurisdiction, with some believed to present very difficult operating environments, and others as more favorable. Factors that may be used in measuring the "friendliness" of a jurisdiction could include rate regulation, residual markets, and market competitiveness. The operating environment for a particular product can also be affected by industrywide events, such as the occurrence of a catastrophe, or a change of law or regulation.

The evaluation of the operating environment can be taken account of in the model through the decision rules for growth, and in the setting of the market product price.

2.4.2 Target Competitive Position

The target competitive position, in an insurance product market which represents a population of insureds with differing risk characteristics, defines a percentile in the distribution of risks, and premiums, where the insurer wants to attract and retain business.

A given insurer is assumed to position itself in its product markets after evaluating its competitive strengths and weaknesses. Companies with, for example, material expense efficiencies can exploit that advantage by offerring lower premiums than its competitors to obtain lower risk insureds at each price level.

In addition to its expense structure, the competitive profile of a company is defined by the quality of its product (the coverage and service delivered to its insureds), its financial solidity and ability to honor its obligations, and its underwriting selectivity. Of these factors, underwriting selectivity is easiest for the insurer's management to vary in the short run.

As we note elsewhere, the competitive market for an insurance product is segmented, and defined by a distribution of prices. Given otherwise identical insurers, their position in the competitive market will be determined by their chosen underwriting selectivity. Having selected a level of underwriting selectivity, and assuming the other factors defining the company's competitive profile are determined, the company's competitive market product price is determined. Thus the cmpany's target competitive position specifies where in the distribution of prices a modeled company intends to compete (the target percentile of its market price).

Having selected a given target competitive position, a company may not be able to realize that target because:

- The market as whole may price irrationally in the short run, either above or below its equilibrium price;
- The company's expense structure, or other aspects of its competitive profile, prevent it from profitably competing at its target level. That is, the price at which the company can cover its costs and earn an adequate return on capital is uncompetitive in the market at the target percentile.

These interactions are an important component of the operating risk of an insurer, and should be reflected in a DFA model.

2.4.3 Underwriting Selectivity

Underwriting selectivity identifies the relative selectivity with which the modeled insurer underwrites risks for a given product. Underwriting selectivity is a critical element in an insurer's success. Unlike other products, the ultimate cost of insurance products is affected by who purchases them. Each potential purchaser has a risk characteristic with respect to the perils covered by the insurance product. In total, the market of potential insureds represents a distribution of risk characteristics. If an insurer is successful in selecting lower risk insureds, the loss cost component of its product cost will be lower.

Modeling competitive market interactions requires explicit consideration of the level of underwriting selectivity. For example, attempts to grow at a rate exceeding the growth rate of the market as a whole, assuming all prices fixed, requires that a company relax its underwriting standards. Because of the interaction between underwriting selectivity and loss cost, changes in selectivity will affect prices as indicated by the pricing algorithm, and thereby, the insurer's financial results.

2.4.4 Target Growth (Reduction)

A fundamental aspect of the insurer's operating plans is the amount of growth in volume desired by product, which can be defined in terms of exposure, premium, or market share. The actual growth can be represented stochastically around the target with interactions with product pricing variables.

In a competitive market, the ability of one company to grow will be constrained by the actions of its competitors. It is certainly possible, using a financial model which does not incorporate the effects of competitive interactions, to create misleadingly optimistic scenarios by coupling unattainable growth rates with profitable prices. We therefore conceptualize growth within a DFA model as two components: a target or planned growth; and the actual growth achieved taking into account the rate of growth for the overall market, the company's relative competitive price position; and relative competitive underwriting selectivity.

2.4.5 Target Underwriting Profit And Contingency Margin

The target underwriting profit and contingency margin, as a percentage of premium, is the underwriting profit and contingency margin entering the pricing algorithm for this product. We noted earlier that the market price, which is derived from the price produced by the pricing algorithm, need not be equal to pricing algorithm price, but, depending upon competitive market conditions, may be higher or lower than the algorithm price.

2.4.6 Residual Market Costs

Residual market costs represent the costs imposed on insurers by law or regulation for the provision of coverage to insureds who, from a regulatory viewpoint, do not otherwise have sufficient access to coverage. Residual market costs can be modeled as a charge per voluntary exposure and/or a percentage charge per dollar of voluntary direct written premium. These charges represent the costs imposed by law or regulation on insurers conducting business in a state and/or line of business to maintain a residual market for coverage and should include assessments by second injury or guaranty funds.

2.4.7 New Versus Renewal Differential

In experience analyses it has been shown that there is a material difference in the experience of newly acquired versus seasoned business. This difference can be critical for companies whose books are changing rapidly, and should therefore be incorporated as a variable in a DFA model. This difference can be reflected in a model as a differential in claim frequency between new and seasoned business, although in actuality it may arise from differences in both claim frequency and severity.

2.5 Operational Characteristics

2.5.1 Reinsurance Protection(s)

Reinsurance is one of the more accessible tools available to management to control operating risk or achieve some limited short run financial effects. Reinsurance protections can be flexibly designed to meet a wide range of needs. Because of the potential use of reinsurance to control some sources of operating risk, evaluating reinsurance contracts is likely to be a prime application of DFA models.

In order to accurately model the effects of different reinsurance protections, a DFA model must include a relatively large parameter set describing the coverage terms and sequence of application of the reinsurance protections (if any) applicable to this product. The reinsurance coverages should be defined, as appropriate, in terms of their applicable retentions, limits, quota share percentage, coreinsurance participations, per occurrence limit, loss adjustment expense treatment, minimum, deposit, and maximum rates, ceding commission terms, reinstatement provisions, reinsurer's margin, ceded premium calculation algorithm, and sequence and scope of application.

2.5.2 Pricing Algorithm

This is the algorithm the model uses to estimate the price required to cover the costs incurred from the sale of the product and produce a competitive return to the company's owners. Since DFA models will often be applied over extended time frames, the model will require an algorithm to determine prices from period to period in the simulation. Without such a reactive pricing algorithm, responding to changes in the modeled experience over time, the output of the analysis will be far from realistic.

There are many algorithms available to determine insurance product prices. It may not be feasible to incorporate all the possible options in a given model. However, in the application of a DFA model to a particular insurer, it is important that the modeled pricing algorithm replicate, as accurately as possible given a limited number of options, the essence of the modeled company's actual pricing process.

2.5.3 Reserving Algorithm

For most property-casualty insurance products, the ultimate cost of that product to the insurer can only be estimated for some period of time after the product sale. The product reserving algorithm, like the product pricing algorithm, defines the components and calculations which the model uses to estimate the ultimate cost of claims associated with this product, and thereby, the reserves which are carried in the insurer's annual statement.

As with the pricing algorithm, there are many reasonable alternatives for the reserving algorithm and we cannot incorporate them all in a given DFA model. The selected algorithm can be deterministic (three year average of previous development) or stochastic (normally distributed around a mean level) and adverse development can also be imbedded in either approach. The resulting reserve should generally not be that implied by the ultimate losses generated by the stochastic claim process, although the algorithm can certainly use them as input. For a variety of reasons, the modeler may want to incorporate the ability to carry reserves in the modeled financial statements which are different from the reserves indicated by the selected reserving algorithm.

As with the pricing algorithm, the selected reserving algorithm should match as closely as possible the essence of the modeled company's actual reserve estimation process.

2.6 Loss Characteristics

2.6.1 Claim Frequency

In order to take into account the stochastic nature of an insurer's experience, a DFA model must incorporate some mechanism to generate claim experience from a random process. The claim process can be modeled at an individual claim level, or at an aggregated level. The trade-offs between these two options are important:

- Modeling at the individual claim level may simply not be feasible from a computation viewpoint given the presently available computer capability. Modeling at this level does, however, allow analysis of the effects of individual claim characteristics without resort to approximation. Modeling changes in coverage (deductibles, coverage limits, per risk reinsurance terms) is straightforward at the individual claim level, but requires more complicated and careful modeling at the aggregated claim or loss ratio level.
- Modeling at an aggregated level allows the use of computationally efficient approximation techniques, which, in many circumstances, are quite accurate. It is not yet clear, however, that aggregated level models will allow modeling of, for example, the interactions between premiums, exposures and losses involved in a competitive market.

2.6.2 Claim Severity

As for claim frequency, this element of the stochastic claim process can be taken into account and modeled at the individual claim level, or at an aggregated level, with the same trade-off issues.

In modeling claim severity, it may also be necessary to model allocated loss adjustment expense separately from losses, if allocated expense treatment has a material impact on the outcomes for the questions being explored by the particular application of DFA techniques. Such treatment may be easier to implement when claim severity is modeled at the individual claim level.

2.6.3 Loss Reporting Pattern And Distribution

The loss reporting pattern specifies the expected sequence with which aggregated losses for this product arising from a given occurrence period will be reported over time, from the date of occurrence. Since variability in this pattern will have a financial effect on the insurer, a DFA model should also consider the distribution around the expected pattern. The randomization of the reporting pattern need not affect the ultimate amount of losses reported, but only the sequence in which the amount determined by the other processes is reported.

2.6.4 Loss Payment Pattern And Distribution

This is the loss payment analog of the loss reporting pattern, the expected sequence with which aggregated losses for this product arising from a given occurrence period will be paid out over time, from the date of occurrence, assuming a corresponding sequence of claim inflation. Variation in the sequence of loss payments is a source of operating risk to insurers and therefore should be reflected in a DFA model. Note that there is a potential interaction between the effect of inflation on claims, and the sequence with which claims are paid. Depending upon the claim inflation model selected, the payment pattern of losses will change over time if the rate of claim inflation changes and this interaction is another potential component of a DFA model.

2.6.5 Premium Collection Pattern And Distribution

These are the premium collection pattern analogs of the loss payment pattern and distribution.The modeling approach to loss reporting, loss payment, and premium collection should be conceptually similar in a given model implementation.

Because of the importance of its loss experience on an insurer's results, the approach taken in modeling the loss process is a defining characteristic of a DFA model. Losses can be modeled at the individual claim level, on an aggregate basis, or (in conjunction with premium) as loss ratios.

The obvious trade-off between individual claim versus aggregate modeling is accuracy for simplicity. This trade-off should be considered carefully, as evaluating reinsurance contracts, specific sub-books of business, or the effectiveness of mitigating strategies on catastrophic losses (such as increased deductibles) will be made much more difficult if losses are modeled at an aggregated level. However, regardless of which model implementation approach is taken (aggregate or individual claims), some careful analysis of the underlying frequency and severity processes, payment and reporting patterns, and their interactions with other relevant variables is vital to the reasonableness of the resulting model.

Loss payment and reporting patterns and their variability is another difficult modeling problem. Most actuaries feel that there is some dependence between the columns (representing common valuation or maturity dates) of a paid or reported loss triangle. Unfortunately, there is no consensus as to the direction, much less the magnitude, of this dependence. This complicates the possible approaches to generating random observations of payment patterns. One possible solution is to develop a concept of "path variance", where the variability of the pattern is associated with the payment or reporting pattern as whole, rather than its incremental components. Another approach is to find a way of restating patterns such that the dependence between successive evaluations is removed.

2.7 Summary

It is dauntingly obvious that a DFA model which takes all of the features mentioned above into account will be extremely complex, in terms of:

- The multiple interactions defined;
- The number of parameters requiring estimation;
- The potential for unstable results;
- The potential for subtle errors (either in defining the array of interactions and relationships among variables, or in programming those relationships).

Our objective in discussing the rather detailed representation of the insurance process above is not to imply that all the features mentioned must be included in a DFA model, but to assist in the analysis of the relative importance of those features. When conducting a DFA analysis, the actuary should carefully consider if the particular modeling context, or objective, is one in which, at the extreme, all of the various product attributes should be recognized in the modeling process, or, alternatively, there are some which can be safely ignored.

3 Insurance Process - Assets

One of the primary concerns with loss reserve opinions is the failure of the opinion to address the ability of the associated asset portfolio to support the liabilities. A DFA model can provide a means of analyzing an asset portfolio as the fund from which an associated reserve will be paid over time. In order to perform this analysis, a DFA model must incorporate the ability to model asset values and their returns over the simulation period, as economic conditions change.

Asset modeling is complex enough to be the topic of many textbooks and articles in professional journals, including those of the actuarial societies. Given that level of complexity, we only attempt to give a brief discussion of asset modeling.

Assets may be defined by the following attributes:

- Yield rates or market interest rate spreads;
- Default rates;
- Term;
- Investment expense;
- Prepayment functions;
- SFAS classification.

Assets can be modeled in a number of ways. The most common modeling technique involves using a "cascade" structure, where first one time series (such as short-term interest rates) is determined, and then those values are used to calculate subsequent series (such as inflation and stock yields). Other time series methods include the use of cointegration or transfer functions. Wilkie provides an instructive, though somewhat long example of the application of this type of modeling.[3]

Alternatively, one can use a model for economy-wide inflation (as measured by the GDP deflator), market values of cash equivalents, Treasury bonds, and large capitalization equities. From these basic components, other asset types can be directly modeled through the use of regression. A key consideration is that for whichever measure of inflation and interest exists in the model selected or developed, the relationships with other operational variables, assets and liabilities, will need to be developed using time series of those indices.

4 Insurance Process - Capital

Insurers require capital, in order to comply with minimum capital requirements imposed by regulation, but more fundamentally, to ensure their ability to survive the inevitable fluctuations in operating results which characterize the insurance business (and the need for DFA). This capital can come from alternative sources (debt, equity, retained earnings), some of which are unique to insurance (surplus notes).

The capital structure of an insurer is constrained by specific laws and regulations on the makeup of its balance sheet as well as by external financial criteria (Risk-Based Capital requirements, insurer rating bureau leverage analyses).

A realistic dynamic financial model should incorporate these constraints and the management responses invoked when the insurer's actual or anticipated operating results bring its financial profile too close to those constraints. For example, growth scenarios should be curtailed when leverage exceeds acceptable levels. This can be effectively handled through the use of decision rules.

5 Insurance Process - Inflationary Effects

Inflation appears to be an unavoidable feature of modern economies and has powerful effects on insurers' operating results. DFA models must therefore specify how inflation is measured and considered. Inflation is generally measured as the change in a price or wage index representing a broad sample of goods or workers. Defining inflation for modeling purposes raises a number of issues:

- Time Horizon - Will inflation be modeled monthly? Quarterly? Annually? This is certainly dependent on how the corresponding asset and liability cash flows are modeled;
- Model - Will the model be of the index or the change in the index?
- Index - Which index will be used? Or will an average of indices be modeled? Will the index representing a time period be that for the end of the period or an average over the period?

Once a times series model of inflation is in place, a model of claim inflation must be developed. While time series or other statistical approaches can be used to analyze the relationship between general economic and insurance claim inflation, there are additional questions whose answers will aid in developing a claims inflation model and its incorporation in a DFA model:

- How does a measure of claim inflation for a specific insurance product relate to the general economic inflation measure? Should this relationship be based on the level of economic inflation or its deviation from some "expected" level (a la Rational Expectations school)?
- Given a measure of claim inflation for a specific insurance product, an index, for example, what specific model of claim inflation should the model incorporate? That is, how does the cost of a specific claim, or group of claims, within the model vary with the claim inflation index?
- (How) does claim inflation affect claim payment patterns and their variability?
- Should the claim inflation effect assumed in the model be uniform by claim size?
- What other effects caused by, or related to, general economic inflation should be incorporated in the model? How should those effects be modeled? For example, is inflation a proxy for other economic events that may affect claim frequency? Market conditions? Reserve adequacy? Etc.

One example of work analyzing the issues raised above is by Butsic (*The Effect of Inflation on Losses and Premiums for Property-Liability Insurers*). In this work, he develops a unified model between two paradigms - the payment date model and the accident date model. Each of the two paradigms relates the period in which the inflation is relevant to the final value of a claim. Butsic designs a model that is a weighted average of the two paradigms, implying that the inflation rate at both the date of loss and the date of payment are relevant. Unfortunately, we have found that the method suggested for calculating the weight is very unstable, depending greatly on the particular data values.

6 Insurance Process - Competition

The risks arising from an insurer's participation in a competitive business are significant. The CAS Dynamic Financial Handbook identifies five major classes of risk to a typical property/casualty insurance company:

- Inappropriate pricing - generally underpricing and often coupled with excessive growth;
- Inappropriate business plan - generally (excessive) growth in areas with significant underpricing or areas for which there is little data or limited company expertise;
- Inappropriate reserving - underreserving due to lack of data, inadequate techniques, and/or management pressure, often coupled with underpricing;
- Inappropriate reinsurance program - a company retains too much risk relative to surplus, or over-relies on a small number of reinsurers who subsequently experience financial difficulty;
- Inappropriate investment portfolio - the company invests too much of its portfolio in asset classes that are overly volatile, poorly understood, or is overly concentrated with a few issuers who subsequently experience financial difficulty. Also, the portfolio could be severely mismatched relative to the cash flow demand of the liabilities during a time when the portfolio is weak.[12]

The first two categories of risk identified are directly related to the competitive market environment in which the insurer operates. The ability of an insurer to price at an adequate level, or to grow at a prudent rate, may be constrained by the actions of its competitors. If the competitive market price for a product does not cover costs, as has happened in some highly competitive markets, it will be difficult or impossible for an individual company to maintain an adequate price for that product.

Pricing below cost is irrational and self-destructive in the long run, but can be seen as a necessary response in the short run during corrections to an imbalance in supply and demand. Versions of the following dynamic have been offered as an explanation of the causes of the underwriting cycle.[8] [29]

- Capital, and capacity, flow into and out of the insurance business as operating loss shocks occur and investor's expectations of returns in insurance compared to other opportunities change over time;
- When capacity is higher, competition is greater, and companies attempt to retain business by following the market to lower prices to avoid the costs of losing, and then attempting to regain, seasoned business (business where the insurer has accumulated knowledge of the insured, the risk he presents, his ability to pay the premiums, and his integrity as a claimant and customer);

- When the cost of selling below cost exceeds the cost of losing and regaining seasoned business, and returns from insurance drop relative to other investments, capacity and prices stabilize;
- This all takes place in a market where information flows are imperfect (insurers' and their investors' estimates of expected returns on existing and future business are uncertain; insurance purchasers do not have complete information about the quality and price of all the products available to them in the market). Imperfect information flows may contribute to the cyclical nature of underwriting returns, and to the persistence of pricing below cost behavior in a down-cycle.

Because the risk of being forced by competitive pressures to price below cost are real, and the effects potentially disastrous, a DFA model whose output is used in formulating an insurer's strategic plan should consider the insurer's competitive environment.

Unfortunately, there are difficulties in modeling the insurance market:

- Insurance product markets are inherently segmented. *The competitive equilibrium price for an insurance product, unlike other products, depends in part on the risk characteristics of the product purchasers. For otherwise identical products, the loss cost, and therefore price, for a product sold subject to stringent underwriting standards will be lower than the price of the same product sold under less stringent standards.* Equilibrium in an insurance product market is therefore defined by: the level of demand for the product; the cost structures of the participating insurers; and by their underwriting selectivities. To the extent that underwriting selectivity differs among the insurers in a given product market, that market is segmented, and the single competitive equilibrium price of traditional economic theory applied to other types of products becomes a distribution of equilibrium prices corresponding to different underwriting selectivities;
- There may be an interaction between changes in an insurer's relative competitive price position and its underwriting results. That is, lower (more competitive) prices may give an insurer the opportunity to attract lower risk (cost) business, and vice-versa. The experience of the insured group, with the addition of the lower risk insureds, may be better than anticipated (based upon the former insured group), and vice-versa. In other industries, a producer's relative competitive price position has no material effect on its cost structure;
- The cost of the product (a contingent promise to pay a variable amount) is uncertain;
- The cost of capital by product is difficult to determine;[13]
- Relevant variables, such as the elasticity of demand, may not be estimable;
- The competitive environment of insurers may be subject to a cycle. While a definitive consensus on the existence and causes of the cycle has not developed, there is agreement that, if underwriting results are affected by an underlying cycle of hard and soft markets, such a cycle will have an important effect on insurers' results, and therefore should be included in a DFA model.[31]

The relevant model implementation questions are:

- What are the mechanics of the transition from cost plus pricing to below cost pricing in insurance markets? That is, what conditions trigger the descent from a competitive equilibrium where prices produce adequate returns to a hyper-competitive market where coverage is offered at below cost prices? What are the mechanics of the recovery from a hyper-competitive market?
- What statistic(s) should be used to describe the competitive environment?
- How can the elasticity of demand for the modeled insurer's product be defined?
- Should factors such as the ease of price changes be incorporated? How?
- Is the modeled insurer's market share an important competitive market model variable?
- In general, how can we model competitive markets at the product level?
- How will the degree of departure from perfect competition affect the model?

7 Insurance Process - Catastrophic Losses

Recent actual experience has demonstrated the importance of the risk of catastrophes as a factor in insurer strategic planning. Relatively new catastrophe exposure analysis models are now available to help quantify the potential frequency and cost of catastrophes, but the problem of incorporating that information in a financial simulation model remain. One important consideration in reflecting catastrophic risk is that the modeler must be very open-minded in considering what belongs in this module of the model. Catastrophes should not just be considered earthquakes and hurricanes, but rather potential shocks to underwriting losses. This includes potential "casualty catastrophes" such as environmental and asbestos, and breast implant claims.

There are three alternatives to modeling an insurer's catastrophe risk within a DFA model.

- Build the capability to model the effect of natural catastrophes into the DFA model itself;
- Provide the results of a separate catastrophe exposure analysis to the DFA model as part of its input, defining the frequency and severity of catastrophes which could affect the company;
- Build a component into the stochastic loss process that "shocks" the frequency and/or severity for catastrophic events.

As most natural catastrophe models analyze data at the zip code or county level, incorporating a catastrophe exposure model within the DFA model will complicate the model in terms of its input requirements, run time, organization and size. However, it also gives the model user the capability to analyze the effects of changes in the company's catastrophe exposure on its overall financial condition, rather than as an isolated element.

The results of an independent catastrophe exposure analysis reflect a particular input (exposure portfolio). Because the effects of catastrophes can vary significantly with the composition of the exposure portfolio (risk characteristics by location, coverage terms and construction), it may not be possible to accurately reflect changes in the exposure portfolio during the simulation time period. Thus the catastrophe risk derived from an analysis independent of a DFA model, used as input to a DFA model, might not truly reflect the catastrophe potential for the company at a given point in the simulation. However, as simulation output is just a sample of potential outcomes, and these outcomes can be adjusted to reflect exposure growth, use of an independent catastrophe model may be a reasonable approach compared to the other alternatives.

The third approach is the most practical when there do not exist any external models and little is known about the potential effects of a given peril. However, it is important when developing this component that events beyond the range of those that have occurred historically are considered as possible.

Finally, if a given DFA model incorporates a component which models competitive market interactions, it will require a method to extrapolate from catastrophe effects on the market as whole to the modeled company, or from the company to the market, since catastrophes can clearly disrupt markets in the affected products and regions.

To summarize, the questions involved in implementing a catastrophe risk component in a DFA model are:

- What events describe the risk of catastrophes in a DFA model? How should they be parameterized?;
- The risk of catastrophes varies by the event and the affected exposure characteristics. How detailed should the partition of events and exposure characteristics be to accurately model the risk of catastrophes and still represent a practical model implementation?
- What is the appropriate relationship between a modeled individual company's catastrophe experience and that of the industry?
- How does one take into account the impact of a catastrophe on the competitive market environment and reinsurance environment?

8 Insurance Process - Decision Rules

We have defined dynamic financial analysis in this paper as modeling an insurance operation over a future time period against a range of potential future operating environments. In that framework, it is relatively easy to devise future operating scenarios which lead to unreasonable financial outcomes during the simulation time period. In the real world, an insurer's management can react to its current and anticipated financial condition and operating environment, revising strategies as necessary, rather than passively continuing an operating plan devised at an earlier time which is now inappropriate in light of current conditions.

A dynamic financial model which does not incorporate reactive management decisions rules is therefore unrealistic. Incorporating such reactive decision rules, however, represents a significant complication in specifying the model. In addition to the specific decision rules, the modeler must also specify what the modeled insurer management is presumed to know about its current and expected future operating environment at a given point in the modeled time frame (management's state of knowledge).

For example, should we assume that management has retained a gifted actuarial seer who can accurately predict future claims inflation so that his predictions should be included in the company's pricing decisions? Alternatively, is it reasonable to assume that the modeled management makes no attempt to estimate its future operating environment given the available past experience?

Once the modeled management's state of knowledge and decision rules are specified in the model, the process of dynamic financial modeling becomes not only an analysis of the financial condition of an insurer in uncertain future operating environments given a defined initial asset, liability (product) and capital structure, but also an analysis of the effects of the modeled management's operating strategies and set of decision rules as incorporated in the model.

Examples of decision rules which could be identified as relevant are:

- Product pricing - In practice, insurance product pricing can involve multiple processes. Rating bureaus can establish prices based on the combined experience of companies. Those bureau prices can serve as benchmarks for individual companies. Pricing at the individual insurer level may involve assorted combinations of bureau- and company-derived rates and relativities as well as individual risk rating modifications. In each of these components there may be both an empirical algorithm (where the available experience data are analyzed as previously discussed) and a managerial decision process (where the results of computational processes are combined with other relevant factors not explicitly reflected in the computation) to arrive at an ultimate pricing decision. To be realistic, a DFA model should incorporate product pricing processes similar to those actually used by the modeled company. While it may not possible to capture the detail of most actual pricing processes, the pricing decision rules reflected in a model should at least reflect the essence of the pricing process of the modeled company, particularly how that process responds to recent past experience and the current competitive environment.

- Investment - If the cash flow from operations is positive, the company can invest the excess over that required for current cash obligations. If cash flow is negative, the company must obtain sufficient cash from the liquidation of some assets, or other sources, to satisfy its current payment obligations. The model therefore requires decision rules to determine how assets are to be invested and liquidated as cash needs change. In addition, investment strategies can potentially vary according to the company's perception of its likely future economic environment, operating results, and tax position.
- Growth/retraction - An insurer's operating objectives can include growth, either as increases in the volume of business for existing products, or expansion into additional products and/or jurisdictions. Growth as an operating objective is an aspect of the broader operating objective of maximizing the value of the firm. Assuming that each business segment (product) can be ranked based on its expected future contribution to the firm's value, management can continuously adjust its investment (allocation of surplus and other resources) among products, growing the business in the more profitable products, and retracting in the less profitable products. A dynamic financial model therefore requires a statement of the rules governing these resource allocation decisions. Because of the potential and actual interactions among products in terms of production, marketing, law and regulation and current commercial practice, the rules governing growth and retraction at the product level can become complex. We also note that operating plans which affect the volume of business affect, and are affected by, the company's expenses, and these interactions must be accounted for (production profit sharing plans and commission levels, for example).
- Loss and loss expense reserve estimation - Insurance is characterized, in part, by the uncertainty in the costs of its products from the time of sale until the settlement of the associated claims. There are available many well-defined actuarial techniques to estimate the ultimate cost of claims after the sale of the product, but prior to ultimate claim settlement. Like pricing, the results of the reserving algorithm may influence management's perception of the company's financial position at any given point in time, but so will other factors that affect the company's operating objectives and strategy. A dynamic financial model should therefore incorporate decision rules for loss and loss expense reserve estimation which replicate the essence of the decision-making process actually used by the modeled company to set its reserves.
- Reinsurance protections - Reinsurance is one of the more accessible, flexible, and potentially effective management tools for an insurer. As the financial condition, size, and product mix of the insurer changes, and/or the reinsurance product market varies, different reinsurance protections become appropriate. The analysis of alternative reinsurance programs is therefore likely to be one of common uses of DFA models. Because of the flexibility of design available for reinsurance programs, it may not be possible to incorporate decision rules describing the company's

reinsurance responses to different operating results, operating environments, and financial conditions. However, alternative reinsurance programs can be tested as sets of input to the model. To the extent that reasonable and realistic rules for the employment of reinsurance can be defined for a given analysis, it may be appropriate to incorporate them in the model structure.

- Dividends - Insurers can issue dividends both to owners of their stock and to policyholders of participating policies. Models can require decision rules to determine the timing and amount of such dividends.

In any application of the model for management decisionmaking, the decision rules modeled should be defined by the management of the insurer being modeled to ensure their appropriateness.

9 Insurance Process - Dependencies

A significant complicating factor in modeling an insurer is modeling the dependencies between variables.[5] That is, changes in the value of a given asset may be related to changes in the value of another asset. Similarly, the experience of one insurance product may vary with the experience of another product. And, finally, the changes in the value of an asset may vary in concert with insurance product experience. This raises some subtle issues. In particular:

- Which variables should be considered dependent? It is possible that all pairs of variables arising from the insurance process will show some dependence as measured by their covariance, based upon a representative set of data. However, the observed dependence may only be a statistical artifact, with no corresponding underlying dependent processes. That is, the variables may be unrelated in terms of the events and causes which determine their ultimate values, but the particular values which entered the data we used to measure their covariance may indicate a statistical dependence. On the other hand, it may be the case that there is some other phenomenon which affects both variables, such that the causal link is indirect, but real nonetheless. A DFA model should incorporate the significant dependencies between assets and liabilities which arise out of direct and indirect causal connections, while separating and ignoring the other spurious dependencies using our understanding of the underlying processes;
- What measure of dependence, or association, among dependent variables is appropriate for implementation in a DFA model? More than one statistical measure of dependence are available. Different measures may be more or less appropriate in the context of a DFA model;
- Having selected an appropriate measure of dependence, how do we impose the dependencies on the variables recognized in the model? This can be done through the explicit modeling of the relationship or through the imposition of a covariance structure. Here, perhaps more than elsewhere, the trade-off between theoretical accuracy and practicability rears its ugly head.

9.1 Correlation

Before venturing down the road of interrelationships, it is worthwhile to discuss the topic of correlation. This is because, although correlation is a commonly used tool to measure the existence of relationships between variables, it is also one that is generally not fully understood.

There are a number of measures of correlation, such as Spearman's rank correlation, Pearson's product moment correlation, and Kendall's tau. These each make different assumptions regarding the underlying distributions of the variables and they each measure different things.

For example, correlation can mean a specific computational result which quantifies an attribute of the relationship between two variables in a sample of model input. In this context, the

Pearson product moment correlation is a measure of the concentration of the input sample about a line fitted to the ordered pairs of that sample.

Correlation can also be interpreted as a measure of the degree of relatedness, or association, between two variables. That is, given the value of one variable, how closely determined is the value of the second by the value of the first?

Correlation can also be interpreted as the tendency of one variable to take on a value above or below its mean value, depending upon the value of a second variable, relative to its mean.[14]

There are a number of methods for imposing a covariance structure on a set of variables. While it is beyond the scope of this paper to fully describe these, we will list a few so the interested reader can research them in an appropriate statistics reference. These methods include normal transformations, the Iman-Conover process, the Cario-Nelson method, as well as time-series approaches like transfer functions, cointegrated series, and, of course, direct modeling.

9.2 Dependencies Among Asset Values

There are many ways to model dependent variables. However, in the exercise of modeling inflation, asset values, and their interdependencies, time-series approaches are a very natural tool to apply. If one uses a cascade model, the first step is to select the independent variable (inflation, for example), not unlike regression analysis. However, rather than regressing, we model this variable on its own, probably using some class of ARIMA (or AR or MA or ...) model. This provides the tools to project future values of inflation.

Once inflation has been modeled, additional series can be modeled using time series containing inflation as some of its terms. Alternatively, inflation can be used to transform the variables (for example, determining real rates of return given the corresponding inflation) or as a regressor to determine a direct relationship. These additional time series and/or functions can then generate, simultaneously with the inflation series, consistent future values. This approach avoids some potentially messy approaches mentioned in the previous section.

9.3 Dependencies Among Liabilities

The experience of different insurance products may be affected by common factors such that the products' experiences tend to vary in concert. The financial impact of deteriorating operating results in several lines together is clearly much greater than the impact of similar, but independent, fluctuations in results by product.[10] Defining and modeling the dependencies among products' experience is therefore an important consideration in a DFA model (see Appendix 7 of Property-Casualty Risk-Based Capital Requirement, A Conceptual Framework, by the Actuarial Advisory Committee to the NAIC Property & Casualty Risk-Based Capital Working Group[26]). Some examples of these dependencies are between:

- Claim frequency by product;
- Claim severity by product and general inflation;
- Recent past industry experience and the level of current competitiveness;
- Recent past reinsurer experience and the price and availability of reinsurance coverage.

With respect to the second example above, the relationship between claim inflation and general economic inflation may vary by insurance product, having the same general behavior for all products and all resulting in greater or lesser dependence between general economic and individual product claim inflation. This would support the hypothesis that there is some correlation between products' experiences caused by the common dependence upon the general economic inflation time series.

In addition, there may be direct relationships between products. This could be a result of geographic concentration, niche marketing, or social/legislative/judicial change. These correlations will need to be modeled directly or externally imposed if they are to be considered in a DFA model. As any assumption of independence between products reduces the variability in potential underwriting results, such an assumption should be analyzed carefully.

9.4 Dependencies Between Assets and Liabilities

At least as important as the dependencies discussed above, the dependencies between assets and liabilities (insurance products) should be considered in a DFA model. As mentioned previously, one can use a general economic time series to derive a corresponding time series of claim inflation. Since assets are related to general inflation and liabilities are related to general inflation, interactions should be revealed through the use of a common source. However, the dependency of assets and insurance product experience arising from inflation is not the only possible relationship between assets and insurance liabilities. There may be other causes, such as a relationship between frequency and inflation, which require research to find, define, and model.

10 Parameter Risk

In modeling, it is generally accepted that there are two types of risk - process risk and parameter (or model) risk. Process risk is the risk that the actual outcome differs from the initial estimate due to random fluctuations. This is akin to the result of two dice being rolled. The expected value is seven, and any observation that is realized which is different from seven (5/6 of the time) is due to process risk. Parameter risk, however, is the risk that the initial estimate of the process is inaccurate. This would come about if the dice were loaded, causing the underlying expectation to not be seven at all. In mathematical terms, process and parameter risk can be described as:

$$\begin{aligned} ProcessRisk &= (X - E) \\ ParameterRisk &= (E - M) \\ TotalRisk &= (X - M) \end{aligned}$$

Where X is the observation, E is the estimate of the process mean, and M is the true mean.

These descriptions may look familiar as they have widespread use in statistics, including the definitions of variance, explanatory power of models, and ANOVA.

Process risk is recognized in DFA models through the use of stochastic variables. However, the modeling of parameter risk is more problematic, perhaps even paradoxical. If one can model the degree and direction that the initial estimate of parameters varies from the true value, why would this error be modeled as parameter risk rather than by revising the parameter estimates? Especially in situations where values are characterized as "best estimates"? In addition, does one need to model the parameter risk of the parameter risk model? And so on?

While it is important to be aware of potential misspecification and/or misparameterization of a model, it is up to the modeler to determine how these potential errors should be addressed. One should also realize that, of the many aspects of the insurance process which can have significant effects on a company's financial results, there may be some which we cannot yet model due to a lack of understanding or data to define their relationships to other model components. For example, it is possible that future reinterpretations of the laws and regulations applicable to insurance will change an insurer's obligations under policies already issued or expired (as has happened with respect to environmental coverage) or that there may be some unforeseen widespread tort activity due to newly discovered health hazards. At this time, we can only recognize that these risks exist. To the extent that we can define the likelihood and effect of such additional risks, they should be recognized in an analysis of an insurer's financial risk. Where they cannot be defined, we can only acknowledge their existence and qualify our analysis appropriately.

11 Miscellaneous Topics

In addition to the aspects of the insurance process considered above, there are some additional issues.

11.1 Stochastic Variables

Recognition of the stochastic features of insurers' operations is a defining characteristic of a DFA model. This can be done by implementing some of the important model variables as observations drawn from distributions that are reasonable representations of those variables. It is ultimately a matter of judgement and computing limitations to designate how many of the variables recognized in the model should be modeled stochastically. For model validation and sensitivity testing purposes it will be desirable to turn off the stochasticity, defaulting the variable to its mean value.

Based upon the previous discussion, stochastic variability can be incorporated in a DFA model via the following variables:

- Variation of planned versus actual growth;
- Competitive market price distribution and the relationship of the competitive market price at any given time to a market equilibrium price which covers costs and provides an adequate return on investment;
- Asset returns;
- General economic and claim inflation;
- Claim frequency and severity by product;
- Loss payment and reporting patterns by product, including run-off of initial reserves;
- The amount of allocated loss adjustment expense incurred for individual claims;
- Expense payment pattern;
- Premium collection pattern;
- The frequency and severity of catastrophic losses for different products and locations.

This list is representative, but by no means exhaustive.

11.2 Accounting and Taxes

Statutory accounting has unique features. Inter-company comparisons and historical analyses are easier to perform when the financial representation of an insurer has been cast in statutory accounting terms. The Federal income tax calculation for insurers proceeds from the statutory accounting results. There are, however, other uses of insurer financial analyses for which other accounting representations are appropriate. The model should therefore be capable of presenting results under statutory,GAAP, and market value accounting. In addition, Federal income tax calculations for insurers are complicated and should be part of the resulting dynamic financial model..

12 Model Output

12.1 Introduction

The most important aspect of model design is to make sure that the model tells you what you need to know. In other words, the specification of the model must include the calculation of output that will be useful to the decision-making process. This is particularly challenging for DFA modelers in that:

- There are many types of management problems to which DFA can be applied;
- The level of output detail necessary to examine all such types may be extensive.

The volume of data potentially generated from a highly detailed model such as the types discussed in this paper is overwhelming. The task of analyzing the data may be easier if we define some types of analyses <u>in the absence of context</u> and then discuss them in detail:

- Expectation and distribution of the objective variable;
- Identification and categorization of scenarios which resulted in extreme values;
- Determination of explanatory variables with respect to the level of the objective variable;
- Evaluation of decision rules, reinsurance programs, etc. relative to the objective variable;
- "Good versus bad" analysis.

12.2 Expectation And Distribution

Given the inclusion of stochastic elements in a DFA model, a primary output of the model should be the distributions of the relevant decision variables. Of interest is not only the expectation and shape of these distributions, but also particular values of the density and/or cumulative distribution functions. Some examples of these include:

- Ending surplus and the associated probability of ruin;
- Operating ratios and the probability of losing money;
- A. M. Best ratings and probability of a ratings downgrade.

Each of these distributions, in addition to its shape and mean, have other interesting features. The scenarios generated by the model can be sorted based on any carried variable to obtain information regarding the variable's probability distribution, and, of course, its moments.

12.3 Identification And Categorization Of Scenarios

It is very difficult to examine thousands of scenarios and dozens of variables for patterns. However, it is not unlike another situation in which we have many observations and need to determine the interactions of the associated variables - classification rating.

Using iterative methods or generalized linear models, one analyzes the objective variable (loss cost, or surplus, for example) trying to determine the effect of individual variables (rating variables, operational variables) on the objective. By using a tool already in the actuarial toolkit and applying it to a different problem, we may have a better grasp of how to approach this challenge.

12.4 Determination Of Explanatory Variables

One possible approach to this analysis is very familiar - multiple regression. This technique allows variables to be fit with coefficients and computes confidence intervals around them. In addition, levels of explanatory power, such as R^2, can be determined. However, it is very important to be aware of the assumptions underlying this technique (such as independent variables) and to interpret the results in the light of informed judgement.

12.5 Evaluation Of Decision Rules, Reinsurance, Etc.

We can evaluate the effect of these model elements in a binary fashion - the rule was either on or off, the reinsurance protection was purchased or not, etc. By separating the scenarios into two sets and comparing the relevant output variable distributions, perhaps through graphical superimposition, differences may be readily apparent. However, it is also important to determine the significance level of these differences and there exist tools, such as the Chi-squared test, to assist the modeler in that task.

12.6 "Good Versus Bad" Analysis

Another desirable feature of DFA is to be able to analyze trade-offs between decisions or scenarios. This can be done graphically with great effect and one of the more well-known applications of this technique is the risk-return plot. This concept can be extended to growth versus loss ratio, reinsurance costs versus ending surplus, or pricing decisions versus market share, to name a few. The graphical approach allows for easy determination of dominated strategies and leaves management with only the decision of where on the boundary of possible strategies they should strive to be.

13 Conclusion

Actuaries have taken on a difficult task in defining and building dynamic financial models of property-casualty insurers. The research and experiments necessary to create such models will, however, benefit our understanding of the insurance business and enable us to contribute more effectively to the management processes of our employers as well as to the regulatory process.

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