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Structure of Actuarial Science [1]

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The primary purpose of actuarial organizations throughout the world is to advance the knowledge of actuarial science. In different countries this objective is perceived in different ways. I propose to present to you some personal perspectives on actuarial science in North America, drawing a distinction between the following four types of actuarial activities.

1. Securing pertinent observations and a better understanding of their nature.
2. Developing realistic models and formulating more comprehensive theories.
3. Modifying parameter values, models and theories for projections and forecasts.
4. Improving operations to ensure greater efficiency and stability.

A selected bibliography on each of these topics, relating mainly to work done in the United States, is appended.

Observations

In the past, actuaries have been concerned predominantly with observations of death rates. The Society of Actuaries and its predecessor body, the Actuarial Society of America, have played leading roles in the accumulation of a comprehensive body of knowledge about mortality. The Reports issues of the Transactions which began about the time the Society of Actuaries was formed provide for a continuing flow of information on current mortality and morbidity on a scale unparalleled elsewhere.

Recent developments in the global economy suggest that the design and pricing of life insurance and pensions are likely in the years ahead to depend far more on the extent of inflation and on the associated investment returns than on mortality. If life insurance and pensions are to remain viable institutions under continuing inflation, they will have to be adapted to rising price levels. Actuaries must, therefore, become as familiar with the facts of inflation, and with investment performance and long-range investment yields under conditions of inflation, as they have been with mortality. In other words, we ought now to

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engage in intensive studies of economic phenomena that bear on actuarial judgments and particularly on the judgments about real investment returns in the long run.

More pertinent and valid facts are also needed in other areas, such as health insurance. The available information about trends in frequency and severity of claims does not adequately explain how and why medical care costs have risen so sharply the last decade. The data are often ambiguous because they reflect not only the incidence and duration of biomedical conditions but also to a major degree differences in medical risk and socioeconomic status. Statistics of functional disability which can be characterized as to degree are now being used to supplement biomedical and socioeconomic measures of morbidity. At a special meeting of the Society of Actuaries in March 1974, much of the discussion of health insurance centered on the meaning of probability statements about disease and disability described in diagnostic terms, and the conclusion reached was that broader definitions of these concepts were in order.

Variations in death rates in different populations have been receiving increasing attention, with emphasis on how the populations under study were selected. The marked gradations observed in death rates by socioeconomic status indicate the magnitude of class selection; the varying levels of annuitant mortality illustrate the effects of self-selection; and the efficacy of different underwriting instruments demonstrates that death rates are materially affected by physical screening. Examination of mortality by cause and duration in diverse groups of lives sheds light on how these different forms of selection operate. In a project conducted jointly by the Society of Actuaries and the Association of Life Insurance Medical Directors, in which medical articles and investigations were reviewed for information bearing on death rates associated with specific diagnoses, it was found that mortality for particular diagnoses has ranged widely in different groups, and that it was influenced significantly by the manner in which the population was chosen.

The magnitude and nature of the fluctuations in experience have also been under investigation lately. The Committee on the Theory of Risk of the Society of Actuaries has been assembling data on the effect of fluctuations in interest, mortality, lapse and expense rates, considered separately and in various combinations, for the purpose of advising actuaries about the margins needed for possible adverse deviations in calculating adjusted earnings of stock life insurance companies.

Models and Theories

Scientific understanding implies ability to explain, control, and predict – three distinct and separate criteria. The strategy for such an understanding is to construct a model or theory, preferably expressed in mathematical language, which would abstract and summarize the permanent features of valid observations, and produce a simplified formal representation of the behavior of a system. Models may be regarded as stepping stones to theories which are intended to provide deeper and more general insights. In this sense, we can appropriately speak of risk theory as reflecting a more fundamental and comprehensive aspect of the processes involved in nonlife and some forms of life insurance. On the other hand, when pertinent observations are scanty or when they vary widely under different circumstances, we are well advised to begin with models rather than theories.

This appears to be the case of economic phenomena. During the 1960's, Great Britain and the United States practiced what were essentially Keynesian policies, while Germany and France combined laissez faire with cartels and bureaucratic direction. Although these countries claim to have followed different economic theories, their practices were nevertheless quite similar. At this time, no single all-embracing economic model appears adequate to explain or predict inflation and investment yields in the long run. In a malfunctioning economy neither the Keynesian nor the monetarist remedies mark out a course for effective solutions, whereas diverse theories can make do in a healthy economy.

On such evidence actuaries have no option but to try to develop their own pragmatic approaches for making conservative estimates of long-range investment returns. It is well to keep in mind that economic analyses have as a rule dealt with short-range equilibrium situations and with idealized markets in which the participants are presumed to be reasonably well-informed. Actuaries, on the other hand, must address themselves to long-range dynamic situations characterized by uncertainty and incomplete information. Stochastic models naturally suggest themselves for this purpose, but the assumption of statistical independence of consecutive observations in an economic time series may reasonably be questioned.

A stochastic treatment of economic problems is consistent with the risk theory approach. It not only facilitates the estimation of long-range investment yields in terms of probabilities, but also explicitly allows for possible discontinuities. A number of econometricians agree on approaching economic problems as stochastic processes. A fundamental contribution to this view was made by

B. Mandelbrot when he came up with impressive arguments, based on both empiric and theoretical grounds, that the movement of commodity and stock prices could be represented by a stable Pareto distribution where price is the random variable. The interest rate is being treated as such a random variable in the models being developed by the Society of Actuaries Committee on the Theory of Risk.

Irrespective of whether we consider the interest rate as a stochastic or a deterministic variable, it appears advisable at this time to elaborate the theory of life contingencies to include the effects of continuing inflation. The theoretical foundations laid by George King and others presupposed a relatively stable monetary system, and the basic equations linking premiums to benefits would be more realistic if they were modified to reflect the diminishing value of money.

In the field of mortality, much work has been done in the United States during the past fifteen years to extend life table techniques and to explore new theories of the death rate. Life-table analysis has been applied systematically to gauge the effects of eliminating or reducing one or more causes of death; this exercise has raised the provocative question of whether the different chronic diseases are actually independent. Deterministic theories of mortality, stressing the genetic element were proposed by Szilard in 1959 and by Strehler and Mildvan in 1960. Brillinger in 1961 reviewed the mathematical expressions for the common laws of mortality from a statistical viewpoint while Sacher and Trucco advanced a complete stochastic theory of mortality in 1962.

In the field of morbidity, the efforts to develop models have been on a more elementary level. One such model was developed on the assumption that disability is of multifactorial origin and postulated morbidity to be a function not only of age, sex and physical condition, but also of income, environment, availability of medical services and other socioeconomic factors. The weights attached to each of the factors and the interrelationships between them have been approximated by multivariate analysis techniques. More sophisticated models of disability have recently been proposed by J. H. Miller and Simon Courant.

Projections and Forecasts

Projections and forecasts are an indispensable component of the actuary's approach to life insurance and pension problems. In formulating a sound financial basis for the payment of future benefits, actuaries have relied heavily on models and theories developed from extrapolations of past experience. The actuary's traditional wisdom has rested on consciously conservative estimates of future costs and on responding promptly to the feedback from ongoing experience. We have been wise to persist in asking the question "What must we do each day to help shape a financially sound tomorrow," but we have approached this question with the expectation of broad continuities.

Recent events have given force to the statement that we are living in an age of discontinuity. There is little in actuarial literature that speaks to the problem of discontinuities. The best we can say is that in making projections we have tried to identify a variety of plausible futures and have explored them with elaborate models and imaginative conceptions of input. Only rarely have we pursued the implications of major departures from past trends or of catastrophic fluctuations.

The time is ripe for greater awareness of potential discontinuities and of their possible impact. The techniques used to detect discontinuities begin with the testing of recent trends for nonrandom variations and proceed to a search for latent or overlooked factors; they include anticipating turning points where exponential growth is approaching physical limits, and bending one's mind to possible interactions that might have drastic consequences. Such an interaction can be illustrated by a sharp drop in the stock market accompanied by high surrenders of equity-linked contracts. There is a growing feeling that common sense expectations of what may follow have been increasingly wrong and that it is extremely difficult to foresee discontinuities arising from political intervention, altered value systems, and major technological breakthroughs. The life insurance business has recognized this problem explicitly by setting up in its industry organization the so-called Trend Analysis Program (TAP) to keep itself abreast of emerging social changes and as an early warning system. The office of Management and Budget in the Federal Government has developed some new statistical series with the same purpose in mind; these figures are intended to serve as indicators of social change, so that those making important decisions might have a better idea of the directions in which events were moving.

In theoretical terms, discontinuities can be envisaged by mapping the probability space of contingencies as revealed by past observations, and enlarging this space to reflect the possible occurrence of highly adverse events through longer tails and greater skewness. Crude estimates of the probabilities of adverse developments are believed to be more illuminating than intuition. Such probability estimates appear particularly appropriate in studies of the surplus funds needed by insurance companies and pension funds.

After weighing the probabilities of future adverse developments more carefully, we can modify the parameter values, models and theories based on past experience in order to make allowance for the greater instabilities of the future. Where there are many variables and the relationships between them are not well understood, we may have to lean on conservative limits or models. However, where more concrete knowledge is at hand, reliance on parameter values at lower probability levels may suggest a more satisfactory answer. A systematic approach to thinking about the future, preferably with the aid of stochastic models, can of itself improve our ability to make better forecasts. It can also bring to light where information to visualize adverse developments is needed and point up the assumptions made about the invariance of certain trends or models. Ultimately we must try to cultivate the art of reasoned conjecture, in order to replace casual intuitions based on past experience with a more calculated and critical analysis of the opportunities in the years ahead.

Improving Operations

After we have carefully assembled pertinent observations, thoughtfully formulated models or theories, and adapted both for projections into the future, we are still confronted with the problems of applying this knowledge effectively in the real world of insurance, pensions, and related financial arrangements.

The responsibility for actual operations in insurance, pensions and related financial arrangements rests with executives or managers; in North America a large proportion of them are actuaries. The role of the individual actuary can run the entire gamut from technical advisor to executive. Given operational responsibilities, the actuary must decide case by case whether to resort to established approaches and common sense judgments or to seek a better solution based on more intensive investigation of the problem. Such a solution may be found in routine application of existing knowledge or it may call for new information and new abstractions from practical operations. The latter type of approach is characteristic of operations research and that is why so many of the techniques of this discipline can be of value to the actuary.

Some of the large life companies in North America have experimented with several of these techniques to see how they might be applied in the insurance business. Long before operations research was recognized as a distinct scientific approach, decisions as to which underwriting instrument to rely upon or which administrative action to take were made on cost-benefit criteria related to the probabilities involved. More recently, queueing theory has been utilized in scheduling computers and in deriving optimal solutions for large scale operations with fluctuating workloads. More sophisticated techniques, such as linear programming, have occasionally been resorted to in problems centering on optimum allocation of time with respect to personnel or resources.

Exploratory simulation is by far the most important operations research tool in insurance and pensions. Powerful electronic equipment has made it possible to trace the consequences of alternative solutions stemming from different models and thus to test various hypotheses embodied in complex corporate models. These procedures have been widely followed in reaching decisions concerning the financial soundness of new forms of insurance or new modes of operation. Thus the Society of Actuaries Committee on the Theory of Risk has recently been simulating the experience of a stock life insurance company to determine the sensitivity of the financial results to various types of fluctuations and changes in experience.

In areas such as marketing, competitive strategies, and personnel utilization, where value judgments are generally involved, it has been found helpful to incorporate in the simulation model payoff measures that reflect the utilities of the decision maker, so that his purposes and preferences become part of the decision function.

An important use of exploratory simulation focuses on a search for policies that will keep the dynamic development of a system within bounds. We can regard such a dynamic development as subject to periodic checks, where the objective is to find ways and means to restore the system to its intended course whenever it departs significantly therefrom. This calls for a theory of multistage control processes, based on some understanding of the causes and effects involved in the departures from the expected development of the system. What we need are both feedforward and feedback controls that would help to ensure the stability of a system.

It must be emphasized that only a limited number of problems are susceptible to the operations research approach. In most situations, the actuary can nevertheless make a very valuable contribution merely by quantifying certain aspects of the total problem, which after all is the first step to modeling. The great merit of more precise quantification can be illustrated in the work recently done by the Society of Actuaries Committee on Cost Comparisons and Related Issues which set out to evaluate different formulas for the cost of life insurance to a policyholder.

To be more effective in improving the practical operations of insurance and pensions, actuaries must learn to tailor solutions to the constraints under which management functions. This requires more explicit training of actuaries as practitioners, giving them a better understanding of the environment in which management decisions have to be made, and teaching them how to articulate professional advice to different audiences. When an actuary is called upon to give advice about operating problems, he must judiciously combine his technical expertise with a sense of the realities in the business world.

One of the main points I would like to make is probably best conveyed by an anecdote. It is the story of an actuary who revisits the university he attended a quarter of a century ago. He goes to see his old professor who shows him the examination questions just set for the class in actuarial science. "Why," inquires the actuary, "your questions are the same as those you put to me years ago." "Yes," replies the professor, "the questions are the same but the answers today are quite different." The structure of actuarial science remains the same, but the answers we want from it now are indeed different.

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Zusammenfassung

Wiedergabe des Vortrags von E. A. Lew an der letzten Mitgliederversammlung über grundsätzliche Gedanken zur heutigen Lebensversicherungsmathematik in den USA. Unterstreicht die Bedeutung brauchbarer Modelle und Methoden zur Behandlung von Teuerung und Zinssatzänderungen, welche im Gegensatz zu früher in den Berechnungen oft stärker ins Gewicht fallen als die Sterblichkeit.

Résumé

Texte du discours tenu par M. le professeur E. A. Lew lors de la dernière réunion des membres sur les idées fondamentales concernant les mathématiques actuelles en assurance-vie aux Etats-Unis. L'accent est mis sur la signification des modèles utiles, sur les méthodes pour traiter le renchérissement et les changements de taux qui pèsent maintenant souvent plus lourd que la mortalité dans les calculs.

Riassunto

Riproduzione del discorso presentato all'ultima riunione dei membri concernente le idee principali nell'attuale matematica d'assicurazione vita negli Stati Uniti d'America. Sottolinea la significazione di modelli utili e di metodi per trattare il rincaro e il cambio dei tassi che – contrariamente ad altre volte – hanno più peso attualmente nel calcolo che aveva la mortalità.

Summary

Wording of the lecture given by Professor E. A. Lew to the members' assembly concerning fundamental ideas on modern mathematics in life insurance in the United States. It emphasizes the importance of useful models and methods for the handling of inflation and changing rates of interest which weigh more heavily today in calculating than mortality did previously.