

MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

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The second "Tagung über Risikotheorie" at the Mathematics Research Center, Oberwolfach, was attended by 43 actuaries, mathematicians, statisticians, and other scientists from a total of 11 countries. Particularly appreciated was the active participation of four North Americans and one Australian.

The 36 papers that were presented demonstrated that risk theory has become a wide field. In a narrow sense it used to be essentially ruin theory. Nowadays, it includes such topics as the calculation of reinsurance premiums, the justification of particular forms of treaties among a group of companies, construction of tariff classes and bonus malus systems, estimation of the pure premium and other parameters of a risk. The principle tools used are methods from probability theory and statistics, operations research, mathematics (for example the extreme value theory for functionals over a quasi convex set). Computers and common sense are essential to many practical actuarial applications.

Classifying the 36 papers is like constructing tariff classes : If few classes are introduced, the classes will be inhomogeneous (reflecting the wide variety of the papers). If complete homogeneity is desired, it is necessary to introduce 36 classes...

As a compromise, the following six classes are proposed (post festum) :

1. Statistics and credibility
2. Bonus-malus and the construction of tariffs
3. Risk exchange and other economical ideas
4. Numerical methods and stop-loss premiums
5. Stochastic models and ruintheory
6. Selected topics.

Abstracts of the papers are given below.

In addition to the nine halfday daytime sessions (where the 36 papers were presented and discussed) there were three evening sessions. One featured a discussion of recursive methods of evaluating a distribution (because of the availability of computers a hot topic in recent years), another was centered around the foundation of credibility (is unbayesed credibility unbased, unbad, bad, or just "a" credibility ?), and the third had an expert talking about Russian game theory.

The "Mathematisches Forschungsinstitut Oberwolfach" was an ideal setting both for the formal and the informal part of the meeting. The participants are extremely thankful for the hospitality of the Institute, and hope that the successful meeting of 1982 will have many successors in the future.

Abstracts

STATISTICS AND CREDIBILITY

"Parametric multiple regression risk models"

Peter Albrecht, Mannheim

Parametric multiple regression models for the claim number and the claim amount are introduced allowing explanatory variables to (even separately) influence the mean claim number (amount). A complete statistical analysis of these models is presented and applications - especially to tariffication in Motor Insurance - are discussed.

"Markov chain models in insurance. Nonparametric inference and analysis of selectional effects"

Ornulf Borgan, Oslo

In recent papers by Aalen (1978, Ann. Statisti. 6, 701-726), Aalen & Johansen (1978, Scand. J.Statisti. 7, 161-171) and Andersen, Borgan, Gill & Keiding (1982, Int. Statist. Rev. 50, to appear) it is shown how the theory of multivariate counting processes provides a general framework in which inhomogeneous Markov chain models may be analysed, and the martingales and stochastic integrals are very useful tools in the study of nonparametric estimation and testing procedures. In the talk I will present some main ideas and results from the above mentioned works and try to indicate how they are of interest also in applied actuarial work. A few comments concerning the possible bias introduced by retrospective studies will also be given (cf. Hoem, 1969, Skand. Aktuar Tidsskr., 147-155).

"A practical application of optimal trimming in credibility"

Alois Gisler, Winterthur

In Switzerland a group of mathematicians was charged with the task of elaborating a new tariffication system for the "Salary compensation in Case of Sickness". The new system should come nearer to the true individual risk premium of each contract. Bichsel & Straub proposed a credibility procedure for this situation. As underlying model they used the Bühlmann & Straub model (1970). The practitioners felt that the proposed credibility estimator has a great disadvantage concerning big claims. If such big claims are fully charged in the credibility formula, single big claims may be the cause of a prescription rise in the estimated premium rate. Hence they raised the question how such big claims should be handled in the credibility formula. The right answer to this question is "Optimum trimming of Data in Credibility" (MVSVM, 1980/3). In this practical application the optimal trimming points in dependence of the premium volumes and the corresponding parameters have been estimated out of the data. Afterwards some simplifications and approximations have been done to make the credibility formula with optimal trimming applicable to practical purposes. The proposed system is now discussed in Switzerland.

"On the problem of estimating ultimate frequency"

William S. Jewell, Berkeley

This problem originates in the field of reliability, where "reliability growth" occurs as systems undergo performance improvement during prototype testing, due to design changes, environmental modifications, and procedural revision. In many cases, only the epochs of the failures are unavailable to the statistician, and there is great interest in using "early returns" to product the ultimate failure rate. This paper constructs a general framework in which to analyze the problem, including many special model variations that have been previously proposed.

Numerical trials indicate the difficulty of using classical MLE estimates, which is unstable for small testing intervals and a small number of systems on test; the MLE is even inconsistent for small intervals, with an unlimited number of systems on test ! Bayersen procedures are recommended for implementation as they can use data from any testing protocol.

"Industry-wide expense standards using random coefficient regression"

Robert B. Miller, Madison

A model establishing industry norms for the relationship between company activity levels and expected operating expenses can provide useful management information. For example, a company could substitute its activity levels into the model, receive the "industry standard" expected expenses, and compare its actual expenses with the "norm".

In this study, data from the annual statements of U.S. life insurance companies are used to derive a multiple regression model. Because of severe multicollinearity, ordinary least squares is an unreliable estimation technique, but, because the model contains many parameters, Bayesian methods prove to be effective. Some recent improvements on Bayesian hierarchical analysis are briefly discussed and illustrated. A predictive analysis confirms the superiority of Bayesian methods over ordinary least squares. Finally, practical questions regarding choice of variables and interpretation of coefficients are addressed.

"Inference about parameters in empirical credibility decision problems. A sampling theoretic approach"

Walter Neuhaus, Oslo

In empirical credibility problems the 1st and 2nd order moments of a structural distribution are estimated by linear techniques. The assumption of randomness of the design in the

collateral data which allows us to derive asymptotic results and use these for inference : Testing, confidence estimation, etc... The methods are applied to a sample of reinsurance data and yield satisfactory results.

"Forecasting of IBNR-claims"

Ragnar Norberg, Oslo

In early papers on the IBNR-problem the run-off scheme has been modelled by a multiplicative structure, each entry being a product of one factor for the accident year, another for the development period, and a third for the payment year (or possibly only one of the last two). The entries may be interpreted as the observable quantities or as their expected values; in both cases the analysis will essentially be the same as long as no further probability structure is added. Later works have given examples of how the model can be probabilized and how forecasts of IBNR-claims arise in a natural way from the model. The present work follows up this approach, starting from quite standard assumptions concerning the risk process. Exact (empirical) Bayes as well as credibility procedures are considered.

"Credibility models allowing durational effects"

Bjørn Sundt, Zürich

In a classical credibility model it is assumed that the claim amounts of an insurance policy from different years are conditionally independent and identically distributed, given an unknown random risk parameter θ . In the present talk, we introduce an additional random variable \tilde{t} , denoting the total time the policy stays in the portfolio. It is assumed that information about \tilde{t} may say something about θ and it should therefore be used in the rating scheme. In the first part of the talk, credibility estimators are deduced and discussed. Then we test whether \tilde{t} says something about θ_0 .

We finally discuss estimation of structural parameters.
A numerical example is given.

"An analytic approach to claims reserving"

Gregory Taylor, Sidney

The problem of analysis of non-life insurance claims experience is examined. An attempt is made to develop a model based, as far as possible, on analytic properties of the experience. Regression methods are used to fit the model to the data. The merits of regression relative to other estimation procedures are considered. The question of second moments of estimates of outstanding claims is considered, and the model currently under consideration applied to it.

BONUS-MALUS AND THE CONSTRUCTION OF TARIFFS

"Bounds for the optimal critical claim size of a bonus system"

Nelson De Pril, Marc Goovaerts, Leuven

The optimal critical claim size of a bonus system determines whether to file a claim with the insurance company after having an accident. The aim of this paper is to demonstrate, within the framework of a simple model, how bounds for the optimal critical claim size can be constructed when only incomplete information on the claim amount distribution is available.

"Tariff construction : principles and methods"

Marc Hallin, Jean-François Ingenbleck, Bruxelles

One of the most intensively treated subjects in the area of actuarial mathematics has certainly been, in the last few years, the problem of theoretical premium calculation. It has however very little influence on current tariff building. The reasons for much a gap between a highly developed theory and its practical applications are multiple; among them is the lack, homewhere between the abstract concept of a risk premium and the concrete amount of money which is collected from policy holders, of a coherent tariff theory. The concept of a "good tariff" itself remains quite fuzzy and undefined. Just as the fairness of a risk premium can be appraised only with reference to a given premium principle, the degree of excellence of a tariff cannot be calculated without some elements of a tariff theory. It is our purpose to give here a brief outline of what this theory should be. No suggest some general principles, and No describe methods for putting them into practice.

The Swedish automobile portfolio will be treated as an example.

"Bonus malus" and premium calculation principles"

Jean Lemaire, Bruxelles

Consider an automobile third-party liability portfolio and suppose - classically - that the number of claims is Poisson-distributed, with a Γ -structure function. If one applies the expected value principle, it is well-known that the merit-rating system resulting from this model

- (i) is financially balanced (constant income for the company)
- (ii) minimizes the mean square error.

The same model is applied to the variance principle and the exponential utility principle. It is shown that those two principles lead to merit-rating systems that do not satisfy the constant income property : in both cases the income decreases with time. Then, the merit-rating systems that result from an absolute loss function, and from a 4th order loss function are computed; an example shows the lack of financial balance (increasing income, in our example).

RISK EXCHANGE AND OTHER ECONOMICAL IDEAS

"Insurance premiums and optimal behaviour of consumers and producers in risk situations"

Fritz Bichsel, Winterthur

I shall present a mathematical model of an economy for which it can be shown that

- without insurance, the overall result of the economy becomes a maximum if the agents of the economy (consumers and producers) decide in risk situations according to the principle of expected values, i.e. choose the option which gives the maximal expected value
- with insurance, the same result is obtained if insurance premiums are equal to the expected value of the claims.

"The general economic premium principle"

Hans Bühlmann, Zürich

An equilibrium risk exchange (a special case of a Pareto-optimal risk exchange) is examined. It is shown that the results that were derived in ASTIN (1980, 52-60) for exponential utility functions can be generalized to arbitrary utility functions. As a consequence one finds a surprisingly explicit description of an equilibrium in the general case. Furthermore, the

existence of an equilibrium is shown by Brouwer's Fixed Point Theorem.

"Risk Exchanges with Partial Information"

Charles Hachemeister, Newark

This paper extends the risk exchange models of Borch, Gerber & Bühlmann and Jewell to the case where the participants recognize different possible events as outcomes. In addition, each participant has different probability estimates of event from those of the other participants. An example using exponential utilities is given.

"Two premium calculation principles by bargaining"

Jean Lemaire, Bruxelles

Part I.

Two premium calculation principles by negotiation. Using, as main tools,

- . the classical risk exchange model by Borch and
- . the bargaining models of Nash and Kalai-Smorodinsky,

we define two new premium calculation principles, whose main goal is to take explicitly into account the attitude towards risk of the policy-holders. Those principles are neither additive nor iterative, but they nevertheless possess several important properties : the premium is translation-invariant, it does not depend neither on the reserves nor on the portfolio of the company; it takes into account all the moments of the claim distribution; it is independent of the policy-holder's wealth but increases with his risk aversion.

Part II.

Coalition against an insurance company. While computing the core of this risk exchange, we show that it can be of the policy-holder's interest to coalize in order to obtain premium cuts.

"Risk Exchange : Fairness and Relative Pareto-Optimality"

Heinz Müller, Zürich

In the theory of risk exchange Bühlmann and Jewell (1978, 1979) have shown that fairness and Pareto optimality lead to a unique solution. This model allows for several interpretations. If the risk belongs to a pool, which has to distribute it among its members the solution can be applied without any difficulty. In the case where all agents are endowed with an initial risk however, the risk exchange should not only be Pareto optimal and fair but also individually rational (i.e. after the risk exchange no agent has to be worse off). Bühlmann and Jewell (1979) have pointed out that these three conditions are not always compatible. Therefore, it may be of some interest to look for a solution which is

- fair
- relative Pareto optimal (i.e. Pareto optimal relative to the set of all fair net trades)
- individually rational.

These requirements are satisfied by "uniform coupons equilibria" a notion borrowed from general equilibrium theory with quantity rationing (Drèze and Müller 1980). In the framework of risk exchange this notion has the following interpretation : an agent who accepts "undesired" parts of a risk portfolio obtains a bonus allowing him to purchase "desired" parts as well. Existence of uniform coupons equilibria can be shown under standard assumptions but no results about global uniqueness are known.

For an exact definition and existence see :

J.H. Drèze, H. Müller : "Optimality Properties of Rationing Schemes, Journal of Economic Theory, Vol 23, no 2, pp. 131-149.

NUMERICAL METHODS AND STOP-LOSS PREMIUMS

"Some Numerical Problems in Risk Theory"

Jürgen Bertram, Manfred Feilmeier, Braunschweig

The computation of the total claim amount's distribution is reduced to the computation of the coefficients of a recursion formula ("Rekursionsformel"). This computation is exemplified for some important claim number distributions. In general recursion formulas are not applicable if there are negative risk sums. In this case a procedure has been developed that heavily relies upon the FFT ("Fast - Fourier - Transformation"). This procedure has been applied to several problems of group-life-insurance. It is going to be applied also to pension-funds.

"Stop-loss dominance"

Etienne de Vylder, Jean Haezendonck and Marc Goovaerts, Belgium

In the theory of finance one studies stochastic dominance decision models for the choice among risky alternatives. The present contribution deals with stop-loss dominance, which to a certain extent represents a complement to stochastic dominance. The influence of both types of dominance to the ordering of claim size and claim intensities is examined.

"Order statistics and largest claims reinsurance"

Erhard Kremer, Hamburg

The lecture deals with the problem of calculating the net premium for the largest claims and ECOMOR reinsurance treaties. Already in 1964 Ammeta derived premium formulas, for which now an easier proof is given. In 1978 Benkander showed that the

premium of the largest claims cover can be bounded by the premium of a corresponding excess of loss treaty plus a multiple of its priority. Now it is proved that under fairly weak assumptions Benktander's bound is asymptotically equivalent to the premium of the largest claims cover; when the size of the collective approaches infinity. Numerical calculations indicate that this equivalence is quite good already for comparable small collectives. A similar result is given for the ECOMOR-treaty. Finally simple distribution-free bounds are deduced for the net premiums of both covers, based only on the knowledge of the mean and standard deviation of the claims size distribution of the risks. The basic tool for proving the theorems is an important branch of mathematical statistics : the theory of order statistics.

"Practical Aspects of Stop-Loss Calculations"

Harry Panjer, Waterloo

Various methods for estimating stop-loss premiums are tested for a real portfolio consisting of 1759 heterogeneous risks. First, premiums are developed from various compound binomial approximations to the aggregate claims distribution under the individual risk model. Secondly, a number of methods are considered for arithmetization of the claim size distribution under the collective risk model. Stop-loss values resulting from the recursive calculation method are then analyzed.

STOCHASTIC MODELS AND RUIN THEORY

"Ruin Theory in the linear model"

Hans U. Gerber, Lausanne

The probability of ruin is examined in a model where the annual gains of an insurance company are dependent random variables. The model used is the linear model (well known in time

series analysis) which includes the autoregressive model and the moving average model as special cases. It is also shown that a certain credibility model can be interpreted as a first order model of the mixed type.

"On risk processes with the Markov property and with independent increments"

Jean Haezendonck, Antwerpen

Let $\{N_t : t \in R_+\}$ be a counting process and $\{X_n : n \in N\}$ a sequence of i.i.d. random variables, independent of $\{N_t : t \in R_+\}$. Consider the "risk" process : $\sum_{n=1}^{N_t} X_n$ ($t \in R_+$).

We study the influence on the underlying counting process $\{N_t : t \in R_+\}$ of the Markov property and of the property of independent increments for the Risk process.

"Semi-Markov processes in risk theory"

Jacques Janssen, Bruxelles

Firstly we begin by giving a summary of the present status of the semi-Markov theory with a finite state space for the first component in the spirit of counting processes. Then we present the completely semi-Markov model in risk theory both for the positive and negative capital models for which we give theoretical results concerning the transient and asymptotical problem of ruin; some useful particular cases are presented to show the connection with classical models and also what it is possible to do from the computational point of view. The junction with the semi-Markov queuing models is also done. Finally, we present shortly some other actuarial models in which the semi-Markov modelization is also used to obtain more judicious models than the classical ones.

"On premium determination and solvency"

Jan Jung, Stockholm

The total claims X_n during year n of a non life branch may be assumed to have an expectation

$$E(X_n) = e_n \xi_n I_n, \text{ where}$$

e_n is the exposure to risk, ξ_n is the expected real claim cost per unit of exposure and I_n is an index of claim cost, different from several consumer price index.

The job of the actuary consists of predicting the ξ_n at the time when in the best case $X_1 - X_{n-2}$ are known.

Suppose he uses a linear predictor

$$\xi_n^* = \sum_{v=2}^k a_v X_{n-v} \text{ to determine } P_n.$$

Then the risk reserve will increase with the surplus $P_n - X_n$, and the resulting reserve U_n can be written

$$U_n = U_0 + \sum_{v=0}^{\infty} b_v X_{n-v}$$

How should the a_v be chosen, in order to

- a) make the premiums change slowly and
 - b) secure that the risk reserve does not vary too fast.
- It seems to be impossible to obtain small variances for both P_n and U_n .

"Models for claim frequencies in a portfolio of property insurance for single family houses and dwelling houses"

Henrik Ramlau-Hansen, K benhavn

At the Laboratory of Actuarial Mathematics, University of Copenhagen, a research project concerning the insurance risk has just been started. The project is organized through the Research Committee of the Danish Actuarial Society, and it is based on an empirical investigation of a portfolio of property insurance delivered by a Danish non-life company. In an empirical

project like this, numerous problems arise, and the talk will emphasize the various models which are available for the description of the occurrence of the claims. Hopefully, it will be possible to show theoretical as well as empirical results from the project.

"Risk Models with Stochastic Discounting"

René Schnieper, Zürich

A discrete time model is proposed for a risk process with discounting factors given by a Markov chain. The process is best described as a random walk with stochastic weights. The moments of the process at a given time (finite or infinite) are determined. In the case of exponentially distributed claims the probability of ruin for a finite time horizon can be computed recursively. In the general case an upper bound is provided for the probability of ruin.

A continuous time model is introduced. It consists in a discounted version of the compound poisson process. The interest rate is thereby a continuous time Markov chain. If the time horizon is infinite the above results still hold.

"Remarks on large claims"

Jef Teugels, Heverlee

Practical situations seem to indicate that some of insurance face the possibility of large claims. We present some ideas on the mathematical problems involved and how they influence procedures traditional in current actuarial circles.

"Some Mathematical Aspects of Reinsurance"

Howard Waters, Edinburg

The speaker considered a single risk for which the insurer had arranged some form of reinsurance, either proportional or excess of loss. In the spirit of two previous papers, Scan. Act. J. (1979) and ASTIN (1980), the effect on the insurer's safety, as measured by his adjustment coefficient considered as a function of the retention limit, as a result of varying the retention limit was examined. It was shown in the case of proportional reinsurance under very general conditions that the insurer's safety varied in an intuitively reasonable way, i.e. that the adjustment coefficient was always a unimodal function of the retention limit. The same result could be proved for excess of loss reinsurance only if some extra conditions were imposed.

SELECTED TOPICS

"Maximisation of a functional of a probability distribution"

Etienne De Vylder, Louvain-La-Neuve

We consider the problem

$$\sup_{F \in \mathcal{F}} (O(F)/C_1(F) = Z_1, \dots, C_n(F) = Z_n)$$

where \mathcal{F} is a family of probability distributions and $O, C_1 \dots C_n$ functions on \mathcal{F} . Under the assumption of existence of a "simple basis" the problem is reduced to the determination of the convex hull of a $(n + 1)$ - dimensional set.

"Optimal Dividend Payments"

Wolfgang Ettl, Wien

Für die Dividendenzahlungen eines Versicherungsunternehmens werden meist sog. "Schranken oder Barrierenmodelle" betrachtet.

Überschreiten die freien Mittel eine bestimmte Höhe, so werden die Beträge über dieser Schranke als Dividende ausgeschüttet. Dieses Modell bewirkt allerdings einen sehr un stetigen und stark schwankenden Verlauf der Dividenzahlungen. Es werden daher gleichbleibend hohe oder nur durch geringe Schwankungen beeinflusst durch das Unternehmensergebnis Dividenden bezahlt. Gleichzeitig soll die Ruinwahrscheinlichkeit nicht über ein bestimmtes Niveau steigen. Unter der Vorgabe eines Bewertungszinsfußes lassen sich jene Dividendenhöhen angeben unter denen der Erwartungswerts des Barwertes aller Dividendenzahlungen maximal wird. Weiters kann der Ertragswert und die Rendite eines Unternehmens betrachtet werden. Es werden mehrere beispielhafte Rechnungen durchgeführt.

"Characterizations of claims distributions by reliability techniques"

Wolf-Rüdiger Heilmann

In the present lecture conceptions of reliability theory are used to characterise the dangerousness of claim distributions. Especially, an estimator of the failure rate is introduced which is appropriate to describe the skemness of sample distributions.

"Asymptotic behaviour of multivariate compound processes"

Christian Hipp, Köln

For large t , the joint distribution of a multivariate compound process $S(t)$ at t is approximated by Edgeworth expansions. A multivariate compound process is constructed with an independent sequence of multivariate claim amounts and a multivariate counting process which is allowed to be stochastically dependent on the claim amounts. The validity of the approximation is proved under a uniform Cramer condition. The terms of the expansion can be given explicitly.

"Influence of inflation on insurance mortality"

Jan Jung, Stockholm

The real mortality rate of insured people depends of age ($x+t$) and of duration t from entrance and might be written

$\theta_t \mu_{x+t}$, where θ_t is increasing from ca 0.3 to 1 in the first 15 years of the insurance. For reasons of simplicity this double-entrance mortality is often replaced by a single mortality function μ_{x+t}^0 , corresponding to the total population. This function is automatically too high in low durations.

Since 1960 about , the fast inflation has caused that the risk sums of new insurances are much higher than those of the old, why, in ordinary death-risk insurance, the payments are less than expected, creating a surplus that may be distributed as bonus. For annuity insurance the same effect causes a loss in mortality payments, which is hidden by the large marge in nominal rate.

"On asymptotically deterministic random variables"

Edgar Neuburger, München

The class of asymptotically deterministic random variables is introduced, which are determined by the fact, that one can reckon with their estimated values in two respects :

- one can expect that the in fact realized variables are sufficiently close to the estimated values
- one can calculate with them, that is, one can use the estimated values in order to derive from them other interesting values,

if a great amount of samples exist.

To estimate asymptotically deterministic random variables, deterministic simulations as well as stochastic simulations are

suitable. With respect to the latter it is possible to show that a single realization may be relied on. Finally, it will be demonstrated by a generalization of the weak law of large numbers, that the proportional numbers (index values), generally used in actuarial practice, are asymptotically deterministic. Therefore, one may reckon with them in the sense above mentioned.

"Asymptotic behaviour of compound distributions and stop-loss premiums"

Bjørn Sundt

We give some asymptotic results for the compound distribution of aggregate claims when the claim number distribution is negative binomial. The special case when the claim numbers are geometrically distributed is treated separately.

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