MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

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Tagungsleiter: H. Bühlmann (Zürich)
W.S. Jewell (Berkeley)
J. Jung (Stockholm)
E. Neuburger (München)

The first "Tagung über Risikotheorie" at the Mathematics Research Center, Oberwolfach, was attended by 46 mathematicians, statisticians, actuaries, and other scinetists from a total of 12 countries.

There were two main reasons for organizing a meeting on this relatively new mathematical subject at this time. The first is that the past 15 - 20 years have seen not only a great increase in the topics considered to be part of risk theory, but have witnessed a veritable explosion in models, methods, and theory, which is reflected in the large number of recent research reports, monographs, texts, and journals devoted to the subject. Meetings such as this one serve to provide perspective on the field as a whole, as well as to bring together researchers from diverse institutions and countries for formal and informal exchange.

The second reason is related to the development of insurance mathematics education in our host country. As there seems to be both a practical and theoretical interest in creating some chairs in this field in Germany, it was hoped to encourage some young and talented mathematicians to work in the field of risk theory.

The formal part of the meeting consisted of nine half-days of lectures. The 33 papers were organized around the following headings:

1. Fields Auxiliary to Insurance
2. Economics and Utility Theory
3. Numerical Methods and Risk Theory in Practice
4. Credibility and Estimation Theory
5. Selected Topics

A balance between state-of the art surveys and recent research results were sought; abstracts of the papers are given below.

At least as important to the participants was the informal part of the meeting, made possible by the superb facilities and smooth functioning of the Mathematics Research Institute. In addition to the daily opportunities for talks in the Schwarzwald hills around Oberwolfach, there was an "organized" hike over hill and dale to the pretty pilgrimage town of St. Roman. And, of course, evenings were devoted to informal but valuable exchange over beer, wine, and other regional specialities.

It is difficult to give an adequate summary of what was a simulating, fruitful, and yet very existential meeting. Two cabalistic symbols remained on the blackboard after all else had been erased:

Bitte nicht löschen:

(Ω, A, P)

X
EX
REX
OREX
POREX
POOREX

but it is difficult to remember whether these were signs of agreement of contention. However, all participants were enthusiastic in expressing their hopes for a repeat Meeting on Risk Theory in the near future.

Bill Jewell (rapporteur)

Abstracts

FIELDS AUXILIARY TO INSURANCE

"Counting processes in life insurance",
Jan Hoem, Copenhagen

A life insurance policy gives rise to a stream of premium payments to the insurer and a stream of benefit payments from the insurer. Each payment stream is described as a stochastic process, and its actuarial value is defined as the expectation of the discounted value of this process at time 0. Three types of payment streams are identified, one of which (general assurance) is analysed in terms of counting processes.

The prospective premium reserve is defined as an expected value at time $t \geqq 0$, conditional on the value of a reserving basis. Retrospective premium reserves have been discussed in the standard actuarial literature for very simple forms of insurance only. Such reserves are now defined for general payment streams, and the relation to their prospective counterparts is investigated. Much of the material is specialized to a general time-continuous Markov chain, in which case Thiele's differential equation becomes a central tool. Its versatility is demonstrated in a study of the consequences of leaving withdrawals out of account, as is common practice in actuarial valuation bases.

"Martingales in Risk Theory",
André Dubey, Zürich

In recent years a number of articles have been published, demonstrating the technique of martingales in risk theory (Gerber, De Vylder, ...). Especially in ruin theory this technique has been used. The basic idea is a theorem of Gerber's: let X_t be a risk process of an insurance company with $X_o = x$. If there exists a decreasing function $v(x)$, with $v(o) = 1$ and $v(\infty) = 0$, such that $v(X_t)$ is a martingale, the ruin probability of the process can be calculated as a factor times $v(x)$.

The existence of such a function $v(x)$ is closely connected with a premium principle, the principle of zero utility: given a utility function u and a risk Y, the premium P is to be calculated in such a way that $u(x) = E[u(x+P-Y)]$. A dynamic approach leads to the condition: the premium process P_t is such that $u(X_t) = u(x+P_t-Y_t)$ is a martingale.

"On the interaction between risk and queueing theories",
Jacques Janssen, Brussels

It is now well-known that there exists a close interaction between risk and queueing theories. However, its strong significance and its contribution to each theory are not sufficiently understood. We give precise relations showing the contributions and the restrictions of this interaction. A general conclusion will be that for the "classical models", many results of queueing theory may be translated into risk theory for the asymptotic case, but the contrary is true for the transient case (i.e. computation of ruin probability in a finite time).

We also consider the significance of different models which can be used in both theories (for example, semi-markovian models and their special cases) and also their possible utility from the practical point of view.

Finally, we will consider the risk-queueing interaction in a larger aspect, taking into consideration the statistical and computing aspects.

"A general equilibrium equation and its applications"

Marc-Henri Amsler, Lausanne

An equilibrium equation is a relation between the risk parameters and the protection parameters of an insurance portfolio. It is general if it holds for an important set of risk types. The Cramèr inequalities and relations can be written (by eliminating the parameters without actuarial meaning) as follows:

$$(P+Q)\cdot\frac{S}{R} = \psi\left(\frac{S}{R}\right)$$

where $P+Q$ = fair net premium + security margin

R = initial risk reserve

$S = -\ln\varepsilon$ = security level, where ε = upper bound of the ruin probability

$\psi(s)$ = logarithm of the moment generating functions of the total claim amount (per year).

This single "general equilibrium equation" leads e.g. to the following applications:

1º premium calculation: to the exponential principle,

2º risk reserve determination: to the formula proposed by Ammeter to the OCDE,

3º pooling: to the estimation of the improvement of the securities concerning the involved portfolios,

4º reinsurance: to the practical determination of net retentions.

"Upper bounds for ruin probabilities in a new general risk model, by the martingale method",

Marc Goovaerts, Leuven, and Florian De Vylder, Louvain-La-Neuve

We consider a portfolio of stochastically variable size in time. It is composed of independent, identical contracts, each of fixed duration, say, one year. The contract number process is a general random point process. The premium income process is defined as follows: for each new contract joining the portfolio, the insurer collects the premium $c(1+\eta)$ at the very instant it joins the portfolio. Here c is the expectation of the claim amount for one contract, and η is the security loading. The insurer is supposed to possess an initial risk reserve u .

Using the martingale method, upper bounds for ruin probabilities (in case of a finite and an infinite planning horizon) are obtained in this model.

The connection with the classical risk model is indicated.

"Estimation of parameters when the variance is infinite"

J.L. Teugels, Leuven

It sometimes happens in insurance business that the total claim amount over a fixed time period is almost exclusively determined by some very large claims.

Mathematically this amounts to a condition on the tail of the probability distribution of the claim amount.

Starting from the hypothesis that this claim amount distribution has a Pareto (Zipf) character, we investigate methods to estimate the main parameter in this law. Among the methods used we mention in particular the asymptotic behaviour of order statistics. Monte Carlo simulation is used to illustrate the theoretical results.

"Some Numerical - Statistical Problems in Risk Theory"

Manfred Feilmaier, Braunschweig

(Abstract not available)

Economics and Utility Theory

"Risk exchanges, Pareto-optima and fairness"

William S. Jewell, Berkeley

A brief survey of utility theory was presented, showing how it justifies, for instance, the purchase of insurance on unfair terms by a risk-averse individual. More complicated risk-exchange agreements were then described, first with a simple variance-reduction example, and then with the following general utility-oriented model from a joint paper with H. Bühlmann on "Optimal Risk Exchanges" (ASTIN Bulletin, 10, (1979), pp. 243-262):

The determination of optimal rules for sharing risks and reinsurance treaties has important practical and theoretical interest. Medolaghi, de Finetti, and Ottaviani developed the first linear reciprocal reinsurance treaties based upon minimizing individual and aggregate variance of risk. Borch then used the economic concept of utility to justify choosing Pareto-optimal forms of risk exchange; in many cases, this leads to familiar linear quota-sharing of total pooled losses, or to stop-loss arrangements. However, this approach does not give a unique, risk-sharing agreement, and may lead to substantial fixed side payments. Gerber showed how to constrain a Pareto-optimal risk exchange to avoid invasion of reserves.

To these ideas, the authors have added the actuarial concept of long-run fairness to each participant in the risk exchange; the result is a unique, Pareto-optimal risk pool, with "quota-sharing-by-layers" of the total losses. There are many interesting special cases, especially when all individual utility functions are of exponential form, giving linear quota-sharing-by-layers. Algorithms and numerical examples are given.

"Prices in Markets of Risk Exchanges"

Hans Bühlmann, Zürich

In the model of risk exchanges

$$\underline{V} = (V_1, V_2, \ldots, V_n) \,, \quad \text{where} \quad V_i(\omega)$$

represents the exchange function of payments received by agent i, if the state ω occurs, the Pareto optimal solutions $\underline{V}$ have been characterized by BORCH in his 1960 paper. Certain Pareto Optima can also be obtained by prices, where a price is defined as a measure Q on all events A. If one allows additional non random transfer payments one even obtains all Pareto Optima. One calculates the price equilibria similarly to the way of obtaining the Pareto Optima from Borch's condition. The Lagrange multiplier in Borch's condition actually can be used to find equilibrium prices. In the case of exponential and quadratic utility functions one finds a universal equilibrium price.

"The Core of A Reinsurance Market"

Jean Lemaire, Brussels

In a series of celebrated papers, K. Borch characterized the set of the Pareto-optimal risk exchange treaties in a reinsurance market. However, the Pareto-optimality and individual rationaltiy conditions, considered by Borch, do not preclude the possibility that a coalition of companies might be better off by seceding from the whole group. In this paper, we introduce this collective rationality condition and characterize the core of this game without transferable utilities in the important special case of exponential utilities. The mathematical conditions we obtain can be interpreted in terms of insurance premiums, calculated by means of the zero-utility premium calculation principle; we then show that the core is always non-void and conclude with an example.

"Pratt's concept of risk aversion in the small: a key to a simple approach to complex models in the actuarial field"

Flavio Pressacco, Trieste

The absolute risk aversion function

$$r_A(x) = -\frac{u''(x)}{u'(x)}$$

is universally adopted to measure the risk aversion associated with an utility function $u(x)$.

Here we investigate and describe the properties of another indicator function of the risk aversion, that is, $p_1(x)$, defined as the probability that satisfies:

$$p(x)u(x+1) + \big(1-p(x)\big)u(x-1) = u(x) .$$

This function belongs to the family $p_h(x)$ of indicators of the risk aversion versus bets of amount h, introduced, jointly with the $r_A(x)$, by Arrow and Pratt.

Indeed, this indicator has a great advantage: it could be immediately extended to describe the risk aversion versus unitary bet in a random situation X (instead of a certain situation x).

This extension in turn provides tools for new insight into the theoretical and practical actuarial problems for the realistic case of monotone decreasing risk aversion.

NUMERICAL METHODS AND RISK THEORY IN PRACTICE

"On the Numerical Evaluation of the Distribution of Aggregate Claims and its Stop-loss Premiums"

Hans U. Gerber, Ann Arbor

Here are 3 methods to evaluate the compound Poisson distribution numerically (discrete case). The most efficient method is based on a recursive formula due to H. Panjer. At the same time, stop-loss premiums are computed recursively.

For an arbitrary claim amount distribution 3 discretization methods are suggested: (a) Method of upper bounds (dispersal); (b) Method of lower bounds (concentration); and (c) Method of matching moments. The latter method seems to produce the most accurate results.

Extensive calculations have been done for a uniform claim amount distribution.

"Risk Theory in Practice (except liability and auto)"

Jan Jung, Saltsjöbaden

The operational profit of a company is the difference between premiums earned and claims costs. Under simplifying assumptions (the yearly claims i.i.d., premiums equal to expected value of claims cost plus known and constant security loading), the classical risk theory studies the process of accumulated profit u_t as function of u_o, the loading η, and the claim's distribution $F(x)$. In real world, the relation is used to control the result by changing u_t, η or $F(x)$ (e.g. by reinsurance). The total risk of the company is a combination of operational risk and investment risk. The operational risk includes risks of adverse trends (inflation or increasing frequency or average claim amount) and random risks. The analysis of risks must be done for homogeneous units, i.e. combinations of insurance class and type of cover, e.g. burglary within home-owners comprehensive insurance. The analysis of these units are based on the claims accounting as illustrated by the run-off triangular scheme. Contrary to the usual theoretical assumptions, the problem of estimating the net risk premium (expected value of the claims) is very difficult. The most recent estimates of claims costs are the most uncertain, as being based on estimated loss reserves. A further complication is the fact, that every class of insurance has its own inflation rate (increase in claims risks for identical damage) which differs from and normally exceeds consumers price inflation.

During the last decades, the trends in frequencies, average damage,and inflation have had much more influence on the solvency than the random variations, which are fairly well checked by reinsurance.

"Risk Theory in Practice, Auto-liability"

Fritz Bichsel, Winterthur

The main task of the actuary is to calculate premiums. The most important part of the premium is the risk premium. By a simple economic model I showed that the risk premium should be equal to the expected value of the claims for each single risk, because then the decisions of the agents in the economy are induced in a way to make the utility of the whole economy a maximum. To estimate the expected value of claims of a risk intuition, intuition must be combined with the methods of statistics and probability. For mass business, it is necessary that the premium can easily be calculated and be based on characteristics of the risk which are easily assertainable. This is in conflict with the aim to adapt the premium as well as possible to each single risk. The way out of this dilemma is experience rating. An example is the Swiss Bonus-Malus-System. I told how it happened that this was introduced in Switzerland. As a further example of practical application of risk theory, I showed how the random fluctuations are smoothed in the calculation of the Swiss Tariff for motor liability insurance.

"On the Computation of the Distribution of the Total Amount of Claims"

T. Pentikäinen, Helsinki

This paper surveys the various methods available for computing the compound Poisson distribution, which is the law governing the distribution of a random number of identical claims. After discussing the few cases where exact calculations are feasible, the following approximation methods are described and discussed: the NP-approximation (improved central limit theorem); the incomplete Gamma-function approximation; Bohman's inversion formula; and the Esscher approximation. In closing, computation by Monte Carlo simulation is discussed.

"Improved Methods for Calculating and Estimating Numerical Stop-loss Premiums"

Wolf-Rüdiger Heilmann, Hamburg

A class of optimization problems is introduced which contains the stop-loss problem from risk theory as a special case. Two abstract optimization models, viz. linear programming in normed vector spaces, and Tschebycheff systems, are presented, and it is shown how to solve the initial problems by methods derived from the general models.

"A nonasymptotic criterion for the evaluation of automobile bonus systems"

Ragnar Norberg, Oslo; Ørnulf Borgan, Oslo, and Jan M. Hoem, Copenhagen.

A new criterion for the evaluation of automobile bonus systems is proposed. It states that a bonus system should be constructed such as to minimize a weighted average of the expected squared rating errors in various insurance periods. The criterion generalizes an asymptotic criterion given earlier by Norberg in 1976. In addition, the new nonasymptotic criterion makes it possible to discuss various short term aspects such as the optimal choice of starting class and the time heterogeneity of risks. Our treatment is illustrated by examples with numerical results.

"On some statistical methods connected with the mixed Poisson process"

Peter Albrecht, Mannheim

In the statistical analysis of the mixed Poisson process two very general approaches are (re-)proposed, and their implementation as well as their properties are considered in detail. Finally some comments on the correct fitting of the heterogeneity model are made.

CREDIBILITY AND ESTIMATION THEORY

"Time-homogeneous models in credibility theory"

Florian De Vylder, Louvain-La-Neuve

Three basic time-homogeneous models are developed:
The model with unweighted observations (Bühlmann);
The model with weighted observations (Bühlmann & Straub);
The hierarchical model (Jewell).

They are preceded by what we call pre-credibility theory where the optimization problem is solved in full generality.

"Credibility in the regression case"

Ragnar Norberg, Oslo

An account is given of the generalization of credibility methods from the case with i.i.d. observations (time homogeneous case) to the general regression situation, defined precisely as the case where the estimand possesses an unbiased linear estimator.

The close connections with other branches of statistical theory are pointed out, viz. Bayesian and empirical Bayes regression, and (classical) random regression coefficient models.

Emphasis is put on the role of credibility methods as robust empirical Bayes techniques. In this context estimation of the 1st and 2nd order moments appearing in the credibility formula is crucial. Properties of unbiasedness, consistency and asymptotic optimalitiy are investigated for a wide class of estimators. An extension to a hierarchical model is included.

"Optimum trimming of data in the credibility model"

Alois Gisler, Winterthur

The practical application of credibility estimation in the field of actuarial activities shows that big claims have distorting effects. On the one hand, such possible large claims exert a big influence upon the variance and trigger off a reduction of the credibility factors. On the other hand, the occurrence of a heavy claim can be the cause of a precipitous rise of the estimated correct premium regardless of the small credibility factor.

In my investigation, I show how the credibility estimator can be improved by trimming the data. The usual credibility model and a model, in which to each risk j and to each year i is given a volume measure P_{ij}, are dealt with. The claim amounts are trimmed at the point M, i.e. subject to the transformation $g_M(x) = \min[M,x]$. Then the semilinear estimator $\hat{\mu}(M)$ is determined, which is linear in the transformed data, and that minimizes the mean squared error among all the linear estimates. M_o is an optimal trimming point, if $\hat{\mu}(M_o)$ is optimal within the class of the estimates $\{\hat{\mu}(M) \mid M \in \mathbb{R}\}$. Next a method is developed to calculate the optimal trimming point if the claim amounts can only assume a finite number of values. Finally there is set forth a method, how the optimal trimming point can be estimated, if the structure function and the distribution of the claim's data are unknown.

With these methods above, all the distorting effects caused by the possible occurence of big claims are eliminated.

"A Model Which Almost Justifies Trimming"

William Jewell, Berkeley (and Hans Bühlmann, Zürich)

What kind of a model would justify trimming as a good approximation to the exact conditional mean? Consider a credibility model in which the original data likelihoods are contaminated by mixing in, with small probability, an excess claim density. Then, it can be shown that the exact regression on one variable, x_1, is :

(a) At first, the predictor increases linearly with x_1, as in ordinary credibility estimation;

(b) But as x_1 gets larger, we begin to believe more and more that it is of excess type, and the regression curve flattens out, passing over a maximum, and then diminishing to the default, no-data estimate of the prior mean.

Except for the "bump", this curve is exactly like Gisler's trim, $\min(x_1, M)$. Similar results hold in higher data dimensions, except that exact calculations require calculating likelihoods for each possible subset of data.

"Credibility of Esscher Premium"

Hans U. Gerber, Ann Arbor

Credibility formulas are discussed for premiums that are calculated according to the Esscher principle. Some of the resulting formulas are of the same appealing type as in the classical case of net premiums.

"Recursive credibility estimation"

Bjørn Sundt, Oslo

We consider an insurance policy, for which claim amounts from different years are conditionally independent given an unknown random parameter θ . If we assume that the claim amounts are identically distributed given θ , the credibility estimator for next year's claim amount based on the claim amounts from previous years will give equal weights to the claim amounts from all the previous years. This has been criticized; one should expect that newer data are more interesting than older data. We are going to modify the model to accommodate this criticism, and we shall assume that the underlying parameter θ changes randomly as time passes (e.g. the abilities of an automobile driver may change). In such cases the explicit expressions for the credibility estimators become complicated, and we shall instead deduce simple recursions for them. For some special cases we shall treat estimation of structural parameters.

"Kalman Filter and Loss Reserving"

Benjamin Zenwirth, North Ryde

The necessity for claims reserves arises out of the usual delays between the event which gives rise to a claim and the ultimate settlement of that claim. To estimate adequate provisions, we need a justifiable forecasting system that employs all the data both objective and subjective. Historic data alone, for example, cannot foresee the effects of impending legislation. Modelling the payment streams using the Kalman filter is a step towards the way out of the current impasse.

"Regression model with scalar credibility weights"

Florian De Vylder, Louvain-La-Neuve

Hachemeister's regression model is modified in such a way that the credibility weights no longer are matrices but simple scalars. This makes the results more appealing (at least in particular situations) and simplifies the parameter estimation problem.

Planning of insurance company time data were demonstrated - for example, the overall value of the assets, the incurred expenses, and the excess payments of the policy holders. A five-year projection of these data was given.

SELECTED TOPICS

"A Model of the Distribution of Wealth"

Wolfgang Eichhorn, Karlsruhe

In 1957, Wold and Whittle published a paper containing a model by which they intended to explain the Pareto distribution of wealth [Econometrica 25 (1957), 591-595]. A complete description of the solutions of the functional-differential equation deduced from their model has been given by Walter. Among these solutions Pareto's distribution is characterized by some remarkable properties. We prove that under the assumptions of the model the distribution of wealth is of Pareto type at any point of time if and only if it was of Pareto type already in the beginning and hence remains so for ever. Additionally we show, by solving an advanced ordinary differential equation, that a multiplicative solution of the functional differential equeation deduced from the model is not necessarily of Pareto type.

"Multicriteria models in reinsurance"

Jean Lemaire, Brussels

The ELECTRE method of multicriteria analysis is applied in order to determine the optimal reinsurance treaty (form of the treaty and retentions) of a company. The size of the portfolio (its mean), its dispersion (variance or coefficient of variation), its danger (ruin probability and skewness coefficient) and finally the cost of the various reinsurance protections are simultaneously considered and intervene in the final decision.

"Some Problems in Personal Lines Insurance Mathematics"

Edgar Neuberger, München

Problem 1: Let $w_1, w_2, \ldots$ be collectives of insureds which are similar in some sense. For each w_i properties q_i are interesting. We know estimates Q_i which are based entirely on W_i, only similarities with the collectives Q_j, $j \neq i$, are not used. We need estimators A_i, which are based on several or all of the $w_1, w_2, \ldots,$ thus using the similarities between the collectives. This problem will only be solved in full if it is proved that all information contained in all collectives is used.

Problem 2: Let us denote k properties of insureds and let $L_k(t)$ be the number of insureds with property k at time t. Finally let $R(t) = q(L_k(t), (k = 1,2,\ldots)$ be other interesting properties. (q is non-linear; the case where q is linear presents no difficulties.) To get the expected value $ER(t)$ one needs Monte-Carlo methods which are very time consuming ("stochastic simulation").

(i) Is it possible to speed up the calculation?

(ii) It is seen by examples that the usual stopping rules do not work. How many simulations are necessary to get reasonable results?

(iii) If the transition probabilities are used as quotas ("deterministic simulation"), the computation becomes much faster. However, the results have a systematic error. Is it possible to decide whether the error is positive or negative, and can one give bounds for the error?

"A multiplicative model of loss reserves. The stochastic process approach"

Per Linnemann, Copenhagen

A non-life insurance company will receive premiums in advance of the risk period insured. At the end of that period it is necessary, therefore, to have reserves to cover unsettled claims. The loss reserve at a given time is the expected present value of all future payments for claims which have arisen by that time, and which may not even have been reported. In the present project, loss reserves are determined from a model with the basic assumption that for each kind of damage, the expected value of the n'th payment on the claim is a product of factors, one for each of the following determinants: waiting time until the claim is reported, waiting time until the relevant payment, inflation, and seasonal variation. The number of payments made to a claim in a given period is taken to be independent of the time at which the damage occurred. The model will be tested and modified on the basis of an extensive set of data on individual claims made available to the project by a major Danish insurance company.

"Claims Reserves in Casualty Insurance, Based on a Probabilistic Method"

Hans Bühlmann, Zürich

Based on a detailed stochastic model, IBNR reserves are estimated and in doing so two different procedures are obtained, one for IBNR (incurred but not reported) and one for IBNER (incurred - and reported - but not enough reserved). The application of four distinct methods (one of them being the classical "lag factor" method) on simulated run off figures shows rather high variances of the estimators. Furthermore, it can be seen that the classical methods lead to surprisingly good results on the numerical data under consideration.

"Stochastic-dynamic models"

Teivo Pentikäinen, Helsinki

A stochastic-dynamic model will be constructed which simulates the flow of insurance business. The ordinary risk items, i.e. claims and investments, administration, etc. are incorporated into the model. The conventional method of risk theory can be amalgamated with the standard analysis and prognostic technique developed for the downstream management of business enterprises. The purpose is twofold: to acquire a program for the future development of business posture, and to relate this information to the future solvency conditions.

"Planning of an Insurance Enterprise"

Peter Gessner, Stuttgart

(Invited talk. Abstract not available.)

Liste der Tagungsteilnehmer

Herrn A l b r e c h t
Dipl.Math.
c/o Herrn Prof. E. Helten
Institut für Versicherungs-
wissenschaft
Universität Mannheim
6800 Mannheim 1, Schloss

Herrn Karl Breitung
Lehrstuhl für Massivbau
der Technischen Universität
Arcisstraße 21
8000 München 2

Prof.Dr. Marc-Henri Amsler
Université de Lausanne
Ecole des H.E.C.
CH-1015 Lausanne-Dorigny

Herrn Prof.Dr. Hans Bühlmann
Mathematik
ETH-Zentrum
CH-8092 Zürich

Professor Bengt van Bahr
Matematiska Institutionen
Stockholms Universitet
Box 6701
S-11385 Stockholm

Dr. André Dubey
Forschungsinstitut für
Mathematik
ETH-Zentrum
CH-8092 Zürich

Herrn Andreas Barner
Mathematik
ETH-Zentrum
HG G36.1
CH-8092 Zürich

Herrn
Prof.Dr. Ernst Eberlein
Institut für Mathematische
Stochastik der
Albert-Ludwigs-Universität
7800 Freiburg i.Br.
Hermann Herder-Strasse 10

Mr. Peter ter Berg
NVVA
Afdeling Statistiek &
Onderzoek
Boerhaavelaan 3
2713 HA Zoetermeer
The Netherlands

Herrn Prof.Dr. W. Eichhorn
Institut für Wirtschaftstheorie
und Operations Research der
Universität Karlsruhe
Kollegium am Schloss, Bau IV
7500 Karlsruhe 1
Kaiserstrasse 12

Herrn Dr. F. Bichsel
WINTERTHUR Schweiz. Versiche-
rungsgesellschaft
General Guisanstrasse 40
CH-8401 Winterthur

Herrn Prof.Dr. M. Feilmeier
Technische Universität
Institut für Rechentechnik
3300 Braunschweig
Pockelstrasse 14

Herrn Prof.Dr. P. Gänssler
Mathematisches Institut
der Ludwig-Maximilian-Universität
8000 München 2
Theresienstrasse 39

Prof.Dr. H.U. GERBER
Department of Mathematics
The University of Michigan
3230 Angell Hall
Ann Arbor, Michigan 48104, USA

Herrn Prof.Dr.P.Gessner
ALLIANZ Lebensversicherungs-
gesellschaft AG
Reinsburgstraße 19
7000 Stuttgart 1

Herrn Dr. Alois GISLER
Lindenbachstrasse 40
CH-8006 Zürich

Prof.Dr. M.J. Goovaerts
Katholieke Universiteit
Instituut voor Actuariële
Wetenschappen,
Dekenstraat 2
B-3000 Leuven

Herrn
Prof.Dr.Wolf-Rüdiger HEILMANN
Institut für Mathematische
Stochastik
Universität Hamburg
2000 Hamburg 13
Bundesstrasse 55

Herrn Prof.Dr. Elmar HELTEN
Institut für Versicherungswissen-
schaft an der Universität
Mannheim
6800 Mannheim 1
Schloss

Prof.Dr. Jan HOEM
Forsikringsmatematisk
Laboratoirum, H.C. Ørsted
Laboratorium
Universitetsparken 5
DK-2100 Copenhagen K

Prof.Dr. Jacques JANSSEN
Université Libre de Bruxelles
av. Jan Stobbaerts 59
B-1030 Bruxelles

Herrn Prof.Dr. W.S. Jewell
Forschungsinstitut für Mathematik
ETH-Zentrum
CH-8092 Zürich

Mr. Jan J u n g
Dir. FSAB, Forsäkringsbranschens
Serviceaktiebolag
Strandvägen 5B
S-11451 Stockholm

Mr. R. Kombrink
c/o Prof.Dr. E. Neuburger
Hochschule der Bundeswehr
FB ET WE1 - Mathematik
Werner Heisenberg-Weg 39
München-Neubiberg

Herrn Prof.Dr. V. Kurotschka
Mathematisches Institut
der Freien Universität Berlin
1000 Berlin 33
Hüttenweg 9

Herrn
Prof.Dr. Edgar Neuburger
Hochschule der Bundeswehr
FB ET WE1 - Mathematik
Werner Heisenberg-Weg 39
München-Neubiberg

Herrn Prof.Dr. Jürgen LEHN
Technische Hochschule
Fachbereich Mathematik
6100 Darmstadt
Schlossgartenstrasse 7

Professor Ragnar Norberg
STOREBRAND IDUN
Haakon VII's gt. 10
Boks 1380 Vika
O s l o 1
Norway

Dr. Jean LEMAIRE
Université Libre de Bruxelles
Institut de Statistique
Campus Plaine C.P.: 210
Boulevard du Triomphe
B-1050 Bruxelles

Herrn Prof.Dr. Ulrich G. OPPEL
Mathematisches Institut
Ludwig-Maximilian-Universität
8000 München 2
Theresienstrasse 39

Herrn
Dr. Franz G. Liebmann
Bundesministerium für Finanzen
Abt. V/6 (Versicherungsaufsicht)
Himmelpfortgasse 4-8
A-1010 Wien

Prof.Dr. José PARIS
Université de Louvain
Institut de Mathématiques Pures
et Appliquées
Place de l'Université 1
B-1348 Louvain-La-Neuve

Mr. Per Linneman
Forsikringsmatematisk
Laboratorium, H.C. Ørsted
Laboratorium
Universitetsparken 5
DK-2100 Cobenhagen K

Prof.Dr. Teivo Pentikäinen
Malmakersvägen 4A
SF-00300 Helsinki 30

Herrn Prof.Dr. V. Mammitzsch
Fachbereich Mathematik
der Universität Marburg
355 Marburg/Lahn
Lahnberge

Prof.Dr. Flavio PRESSACCO
Università di Trieste
Istituto di Matematica
Finanziaria
Trieste, Italy

Mr. Nelson De Pril
Lic.sc.math.
Tiensestraat 201
Bus 13
B-3000 Leuven

Professor Jef Teugels
Department of Mathematics
K.U. Leuven
200 B Celestijnenlaan
B-3030 Heverlee, Belgium

Herrn René Schnieper
Mathematik
ETH-Zentrum
CH-8092 Zürich

Prof.Dr. Fl. De Vylder
315, Steenweg op Ninove
B-9400 Denderleeuw
Belgium

Herrn Dr. Erwin Straub
Schweiz. Rückversicherungs-
Gesellschaft
Mythenquai 50-60
CH-8002 Zürich

Herrn Dr. Werner Wierich
c/o Herrn Prof.Dr. V. Kurotschka
Mathematisches Institut der
Freien Universität Berlin
1000 Berlin 33
Hüttenweg 9

Herrn Jürgen Strauss
Leitender Mathematiker der
Münchener Rückversicherungs-
Gesellschaft
8000 München 40
Königinstrasse 107

Herrn Prof.Dr. H. Witting
Institut für Mathematische
Stochastik der
Albert-Ludwigs-Universität
7800 Freiburg i.Br.
Hermann Herder-Strasse 10

Dr. Björn Sundt
Forschungsinstitut für
Mathematik
ETH-Zentrum
CH-8092 Zürich

Professor Benjamin Zenwirth
c/o Laboratory of Actuarial
Mathematics
University of Copenhagen
Universitetsparken 5
DK-2100 Copenhagen Ø