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Geneva Papers on Risk and Insurance Theory

Volume **27** (2), 2002

Barrieu, P. & El-Karoui, N. *Reinsuring climatic risk using optimally designed weather bonds.* 87-113. The aim of this paper is to determine the optimal structure of a weather bond, ie a bond whose coupons depend on the occurrence of a weather event. The stress is put more on the structuration than on the simple pricing of the bond. Therefore, instead of looking only at the bond issue, we consider it as a part of a more general transaction, involving three agents: a firm, which wants to be hedged against its weather risk, an investor, which buys the bond and a bank, which has an intermediary key role. Then, we derive the optimal characteristics of the whole transaction. But the bond structure which is obtained, corresponds to a minimal structure: indeed, only the bond optimal price function and its optimal reimbursement level (among which is paid back when an event occurs) can be determined while there is a degree of freedom in the choice of the optimal coupon. Therefore, this indeterminacy may be interpreted as a marketing tool and it could play an important role in the negotiation process between the issuer and the investor.

Fagart, M.-C., Fombaron, N. & Jeleva, M. *Risk mutualization and competition in insurance markets.* 115-141. The aim of this paper is to analyze the impact of mutual firms on competition in the insurance market. We distinguish two actors in this market: mutual firms, which belong to their pooled members, and traditional companies, which belong to their shareholders. Our approach differs from the literature by one crucial assumption: the expected utility of the consumers depends on the size of their insurance firm, which generates network externalities in this market. Thus, the choice of a contract results in a trade-off between the premium level and the probability of that premium being ex-post adjusted. The optimal contract offered by a mutual firm involves a systematic ex-post adjustment (negative or positive), while the contracts a company offers imply a fixed premium that is possibly negatively adjusted at the end of the contractual period. In an oligopoly game, we show that three types of configurations are possible at equilibrium: either one mutual firm or insurance company is active, or a mixed structure emerges in which two or more companies share the market with or without a mutual firm.

Froot, K. A. & Posner, S. E. *The pricing of event risks with parameter uncertainty.* 153-165. Financial instruments whose payoffs are linked to exogenous events, such as the occurrence of a natural catastrophe or an unusual weather pattern depend crucially on actuarial models for determining event (eg default) probabilities. In many instances, investors appear to receive premiums far in excess of these modeled actuarial probabilities, even for event risks that are uncorrelated with returns on other financial assets. Some have attributed these larger spreads to uncertainty in the probabilities generated by the models. We provide a simple model of such 'parameter uncertainty' and demonstrate how it affects rational investors' demand for event risk exposures. We show that while parameter uncertainty does indeed affect bond spreads, it does not tend to increase spreads by much. Indeed, the spread increases due to parameter uncertainty in our numerical examples are on the order of only 1-2 basis points. Moreover, in many instances, including those that have the most sensible correlation settings, parameter

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uncertainty tends to decrease the size of bond spreads. We therefore argue that parameter uncertainty does not appear to be a satisfactory explanation for high event-risk returns.

MACMINN, R. *On the judgment proof problem.* 143-152. A party who causes harm to others and is found legally liable but cannot fully pay is said to be judgment proof. When the party who causes the harm is judgment proof, the incentives provided by the negligence and strict liability rules diverge. The payment probabilities implied by the two rules also differ. If the cost of care is non-monetary, as in Shavell's analysis, then the different probabilities generated by the two rules and the injurer's risk aversion combine to show that greater care is optimal under the negligence rule than the strict liability rule. If, however, the cost of care is monetary then the difference in probabilities generated by the two rules suffices to show greater care under the strict liability rule than under the negligence rule. The latter case holds for either a risk averse injurer or a corporate injurer.

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INSURANCE: MATHEMATICS & ECONOMICS

Volume **31** (1), 2002

DE SCHEPPER, A., GOOVAERTS, M. J., DHAENE, J., KAAS, R. & VYNCKE, D. *Bounds for present value functions with stochastic interest rates and stochastic volatility.* 87-103. The present value of a series of cash flows under stochastic interest rates has been investigated by many researchers. One of the main problems in this context is the fact that the calculation of exact analytical results for the distribution of this type of present values turns out to be rather complicated, and is known only for special cases. An interesting solution to this difficulty consists of determining computable upper bounds, as close as possible to the real distribution.

In the present contribution, we want to show how it is possible to compute such bounds for the present value of cash flows when not only the interest rates but also volatilities are stochastic. We derive results for the stop-loss premium and distribution of these bounds.

DHAENE, J., DENUIT, M., GOOVAERTS, M. J., KAAS, R. & VYNCKE, D. *The concept of comonotonicity in actuarial science and finance: theory.* 3-33. In an insurance context, one is often interested in the distribution function of a sum of random variables. Such a sum appears when considering the aggregate claims of an insurance portfolio over a certain reference period. It also appears when considering discounted payments related to a single policy or a portfolio at different future points in time. The assumption of mutual independence between the components of the sum is very convenient from a computational point of view, but sometimes not realistic. We will determine approximations for sums of random variables, when the distributions of the terms are known, but the stochastic dependence structure between them is unknown or too cumbersome to work with. In this paper, the theoretical aspects are considered. Applications of this theory are considered in a subsequent paper. Both papers are to a large extent an overview of recent research results obtained by the authors, but also new theoretical and practical results are presented.

GÓMEZ E., HERNÁNDEZ, A., PÉREZ, J. M. & VÁZQUEZ-POLO, F. J. *Measuring sensitivity in a bonus–malus system.* 105-113. In performing Bayesian analysis of a bonus–malus system (BMS) it is normal to choose a parametric structure, $\pi_0(\lambda)$, in the insurer's portfolio. According to Bayesian sensitivity analysis the structure function can be modelled by specifying a class Γ of priors instead of a single prior. In this paper, we examine the ranges of the

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relativities, i.e. $\delta^{\pi} = \mathbb{E}[\lambda\pi(\lambda|\text{data})]/\mathbb{E}[\lambda\pi(\lambda)], \pi \in \Gamma$. We illustrate our method with data from [Astin Bulletin 10 (3) (1979) 274].

HABERMAN, S. & VIGNA, E. *Optimal investment strategies and risk measures in defined contribution pension schemes.* 35-69. In this paper, we derive a formula for the optimal investment allocation (derived from a dynamic programming approach) in a defined contribution (DC) pension scheme whose fund is invested in n assets. We then analyse the particular case of $n = 2$ (where we consider the presence in the market of a high-risk and a low-risk asset whose returns are correlated) and study the investment allocation and the downside risk faced by the retiring member of the DC scheme, where optimal investment strategies have been adopted. The behaviour of the optimal investment strategy is analysed when changing the disutility function and the correlation between the assets. Three different risk measures are considered in analysing the final net replacement ratios achieved by the member: the probability of failing the target, the mean shortfall and a value at risk (VaR) measure. The replacement ratios encompass the financial and annuitisation risks faced by the retiree. We consider the relationship between the risk aversion of the member and these different risk measures in order to understand better the choices confronting different categories of scheme member. We also consider the sensitivity of the results to the level of the correlation coefficient.

SHAPIRO, A. F. *The merging of neural networks, fuzzy logic, and genetic algorithms.* 115-131. During the last decade, there has been increased use of neural networks (NNs), fuzzy logic (FL) and genetic algorithms (GAs) in insurance-related applications. However, the focus often has been on a single technology heuristically adapted to a problem. While this approach has been productive, it may have been sub-optimal, in the sense that studies may have been constrained by the limitations of the technology and opportunities may have been missed to take advantage of the synergies between the technologies. For example, while NNs have the positive attributes of adaptation and learning, they have the negative attribute of a 'black box' syndrome. By the same token, FL has the advantage of approximate reasoning but the disadvantage that it lacks an effective learning capability. Merging these technologies provides an opportunity to capitalize on their strengths and compensate for their shortcomings.

STEFFENSEN, M. *Intervention options in life insurance.* 71-85. We deal with the intervention options of the policy holder in life insurance. To these options belong the surrender and the free policy (paid-up policy) options. Our approach is to let payments be driven by processes in which the policy holder is allowed to intervene. The main result is a quasi-variational inequality describing the market reserve on an insurance contract taking into account intervention options. The quasi-variational inequality generalizes Thiele's differential equation used for calculation of reserves on a policy without intervention options. It also generalizes the classical variational inequality used for calculation of the price of an American option.

INSURANCE: MATHEMATICS & ECONOMICS

Volume **31** (2), 2002

BASU, S. & DASSIOS, A. *A Cox process with log-normal intensity.* 297-302. In this paper we look at pricing stop-loss reinsurance contracts using an approximation technique similar to that of Basu (PhD Thesis, London, 1999) and Rogers and Shi [J. Appl. Probability, 32] for processes with constant claims and the underlying stochastic intensity following a log-normal distribution. In particular, we look at the Cox process with the underlying stochastic intensity being log-normal.

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CASTAGNOLI, E., MACCHERONI, F. & MARINACCI, M. *Insurance premia consistent with the market.* 267-284. We consider insurance prices in the presence of an incomplete and competitive market. We show that if the insurance price system is internal, sublinear, and consistent with the market, then insurance prices are the maxima of their expected payments with respect to a family of risk neutral probabilities. We also show that under a simple additional assumption, it is possible to decompose the obtained price in net premium plus safety loading.

DHAENE, J., DENUIT, M., GOOVAERTS, M. J., KAAS, R. & VYNCKE, D. *The concept of comonotonicity in actuarial science and finance: applications.* 133-161. In an insurance context, one is often interested in the distribution function of a sum of random variables. Such a sum appears when considering the aggregate claims of an insurance portfolio over a certain reference period. It also appears when considering discounted payments related to a single policy or a portfolio, at different future points in time. The assumption of mutual independence between the components of the sum is very convenient from a computational point of view, but sometimes not a realistic one. In *The Concept of Comonotonicity in Actuarial Science and Finance: Theory*, we determined approximations for sums of random variables, when the distributions of the components are known, but the stochastic dependence structure between them is unknown or too cumbersome to work with. Practical applications of this theory will be considered in this paper. Both papers are to a large extent an overview of recent research results obtained by the authors, but also new theoretical and practical results are presented.

DIJKSTRA, T. K. & YAO, Y. *Moment generating function approach to pricing interest rate and foreign exchange rate claims.* 163-178. This paper uses moment generating functions to provide a general framework to model international term structures and to price interest rate and foreign exchange rate claims. When moment generating functions of state variables have a closed-form formula, closed-form formulas for bond prices are available for a large variety of functional forms for the state price density. When state price densities are specified as exponential functions of Ornstein–Uhlenbeck processes or Cox–Ingersoll–Ross processes, closed-form formulas can be obtained for interest rate and foreign exchange rate futures, options and swaps.

DOS REIS, A. D. E. *How many claims does it take to get ruined and recovered?* 235-248. We consider in the classical surplus process the number of claims occurring up to ruin, by a different method presented by Stanford and Stroiński [Astin Bulletin, 24]. We consider the computation of Laplace transforms (LTs) which can allow the computation of the probability function. Formulae presented are general.

The method uses the computation of the probability function of the number of claims during a negative excursion of the surplus process, in case it gets ruined. When initial surplus is zero this probability function allows us to completely define the recursion for the transform above. This uses the fact that in this particular case, conditional time to ruin has the same distribution as the time to recovery, given that ruin occurs.

We consider also the computation of moments of the number of claims during recovery time, which with initial surplus zero allows us to compute the moments of the number of claims up to ruin. We end this work by giving some insight on the shapes of the two types of probability functions involved.

JUMARIE, G. *Stock exchange dynamics involving both Gaussian and Poissonian white noises: approximate solution via a symbolic stochastic calculus.* 179-189. One considers the stock exchange stochastic dynamics obtained when a Poissonian white noise is added to the usual Gaussian white noise. The generalized Kolmogorov equation (GKE) defining the probability density of this process is well known, but here, by using a symbolic stochastic calculus of order

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n, one can obtain an approximate expression for the state of this process. As an application, a Black–Scholes equation of order n is derived without explicitly using Itô's lemma for Poissonian stochastic differential equation.

KLIGER, D. & LEVIKSON, B. *Pricing no claims discount systems.* 191-204. We price a no claims discount (NCD) system, in which the insured receives a discount (d) in the absence of claims for k years. The paper gives optimal decisions for both the insured and the insurer, using Markov decision processes and game theory. The company fixes a premium (π) and a discount (d), accounting for the reaction of the insured. The insured decides whether to claim, given the offered contract, the realized damage level, and the number of years without claims. The insured's optimal behavior is described by a set of damage threshold values, below which claiming is not worthwhile.

KÜHN, C. *Pricing contingent claims in incomplete markets when the holder can choose among different payoffs.* 215-233. We suggest a valuation principle to price general claims giving the holder the right to choose (in a predefined way) among several random payoffs in an incomplete financial market. Examples are so-called 'chooser options' and American options with finitely many possible exertion times but also some life insurance contracts. Our premium is defined by the minimal amount the writer must receive at time zero such that for all possible decision functions of the holder, the writer's utility is at least as big as the utility he would have if he did not offer this contingent claim. The valuation principle is consistent with no-arbitrage and can be interpreted as a generalization of Schweizer's indifference principle (Schweizer [IME 28]). We show that in a complete financial market or, in general, if the writer has an exponential utility function, our premium is the supremum over all 'utility-indifference premiums' related to all fixed random payoffs we get by fixing the decision function of the holder. For every other utility function our premium can be even larger than this supremum.

MASHAYEKHI, M. *On asymptotic optimality in empirical Bayes credibility.* 285-295. In this paper we consider linear empirical Bayes estimation of the pure premiums in a Bühlmann–Straub model, with m risk contracts and n_i observations from the ith contract, and provide sufficient conditions, analogous to the conditions of Norberg [SAJ (1980)], for a stricter notion of asymptotic optimality. The sufficient conditions are used in the paper to show asymptotic optimality of explicit non-parametric examples. Our results, among other things, strengthen the estimators proposed by Bühlmann and Straub (1970) and their generalization by Sundt (1983). They also strengthen the finite population mean estimators of Ghosh and Lahiri (1987) by showing the asymptotic optimality of their estimators under a weaker condition than the boundedness of the moments of fourth order.

MENONCIN, F. *Optimal portfolio and background risk: an exact and an approximated solution.* 249-265. This paper analyses the portfolio problem of an investor maximizing the expected exponential utility of his terminal real wealth. The investor must cope with both a set of stochastic investment opportunities and a set of background risks. If the market is complete we are able to find an exact solution. If the market is incomplete, we suggest an approximated general solution. Contrary to other exact solutions obtained in the literature, all our results are obtained considering a stochastic inflation risk and without specifying any particular functional form for the stochastic variables involved in the problem.

PALMOWSKI, Z. *Lundberg inequalities in a diffusion environment.* 303-313. In this paper we consider a Cox process driven by a Markov process. We Markovise the Cox process by adding the supplementary governing component and we find the extended generator $\mathcal{A}$ of such constructed process and its domain $\mathcal{D}(\mathcal{A})$. As an example we discuss a risk process with a Coxian arrival process generated by a diffusion process. For this process we derive Lundberg inequality for the ruin probability.

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YUEN, K. C., GUO, J. & WU, X. *On a correlated aggregate claims model with Poisson and Erlang risk processes.* 205-214. In this paper we consider a risk model with two dependent classes of insurance business. In this model the two claim number processes are correlated. Claim occurrences of both classes relate to Poisson and Erlang processes. We derive explicit expressions for the ultimate survival probabilities under the assumed model when the claim sizes are exponentially distributed. We also examine the asymptotic property of the ruin probability for this special risk process with general claim size distributions.

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JOURNAL OF RISK AND INSURANCE

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BONATO, D. & ZWEIFEL, P. *Information about multiple risks: the case of building and content insurance.* 469-487. Insurers traditionally use risk-specific characteristics of insureds to classify them according to risk. In this article, the practical relevance of information about multiple risks is demonstrated for the case of content insurance of a Swiss company. Two types of such information prove important: information about 'spillover moral hazard' caused by mandated prevention affecting preventive effort in an unregulated line, and information about 'common impulses' reflected in the loss experience of related lines. Both contribute to an improved prediction of loss probability.

DEVLIN, R. A. *Determinants of no-fault insurance measures.* 555-576. In spite of being touted as the panacea for rising premiums and unfair settlements, no-fault automobile insurance provisions exist in fewer than one third of U.S. states. Few researchers have examined why such measures exist in some states but not in others. This article focuses directly on this issue by looking at the factors that help explain the type of no-fault regime in place. The article conducts an empirical analysis using a data set that spans all 50 states over the 19-year period from 1972 to 1990. Among other things, the analysis finds that the structure of the insurance industry and the type of rate regulation under which it operates are determinants of these decisions.

GRÜNDL, H. & SCHMEISER, H. *Pricing double-trigger reinsurance contracts: financial versus actuarial approach.* 449-468. This article discusses various approaches to pricing double-trigger reinsurance contracts — a new type of contract that has emerged in the area of 'alternative risk transfer'. The potential coverage from this type of contract depends on both underwriting and financial risk. We determine the reinsurer's reservation price if it wants to retain the firm's same safety level after signing the contract, in which case the contract typically must be backed by large amounts of equity capital (if equity capital is the risk management measure to be taken). We contrast the financial insurance pricing models with an actuarial pricing model that has as its objective no lessening of the reinsurance company's expected profits and no worsening of its safety level. We show that actuarial pricing can lead the reinsurer into a trap that results in the failure to close reinsurance contracts that would have a positive net present value because typical actuarial pricing dictates the type of risk management measure that must be taken, namely, the insertion of additional capital. Additionally, this type of pricing structure forces the reinsurance buyer to provide this safety capital as a debtholder. Finally, we discuss conditions leading to a market for double-trigger reinsurance contracts.

HARDWICK, P. & ADAMS, M. B. *Firm size and growth in the United Kingdom life insurance industry.* 577-593. This study tests whether the organic growth rates of United Kingdom (U.K.) life insurance firms are independent of size, as predicted by Gibrat's (1931) Law Of

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Proportionate Effects. Using data for 1987-1996 and the three subperiods, 1987-1990, 1990-1993, and 1993-1996, we find that smaller life insurance firms tended to grow faster than larger ones in the 1987-1990 period and that larger life insurers tended to grow faster than smaller ones in the 1990-1993 and 1993-1996 periods. But over the ten-year period, we find no significant difference between the growth rates of small and large firms, thus supporting Gibrat's Law as a long-run tendency in the U.K. life insurance industry. When we examine firm-specific determinants of asset growth, we find evidence in 1987-1996 and 1987-1990 that more diversified life insurance firms experienced higher growth rates on average than more specialized life insurers. We also find that the growth of life insurance firms was related to input costs during the 1990-1993 and 1993-1996 subperiods.

Seog, S. H. *Equilibrium price dispersion in the insurance market.* 517-536. We consider price dispersion under nonsequential consumer search when a finite number of firms exists. We assume that firms have the same production technology. We find that single-price equilibrium exists only when it is the highest possible price (monopoly price). Price dispersion is possible in equilibrium only when firms use mixed strategies. We also find that increased competition may increase price dispersion and the intensity of consumer search while reducing the expected profits of firms. The number of firms in the long run is increasing regarding expected market demand and decreasing regarding production cost and entry cost. We reinterpret some empirical observations reported in the literature.

Spahr, R. W., Schwebach, R. G. & Sunderman, M. A. *Original-issue systematic and default risk pricing efficiency of speculative-grade bonds.* 489-516. We investigate whether primary market, original-issue risk premiums on speculative-grade debt are justified solely by expected defaults or whether these risk premiums also include other orthogonal risk components. Studies of secondary-market holding period risk and return have hypothesized that risk premiums on speculative-grade debt may be explained by bond- and equity-related systematic risk and possibly other types of risk. Using an actuarial approach that considers contemporaneous correlation between default frequency and severity and first-order serial correlation, we cannot reject the hypothesis that the entire original-issue risk premium can be explained by expected default losses. This suggests that speculative-grade bond primary markets efficiently price default risk and that other types of risk are priced as coincident as opposed to orthogonal risks.

Urrutia, J. L., Vu, J., Gronewoller, P. L. & Hoque, M. *Nonlinearity and low deterministic chaotic behaviour in insurance portfolio stock returns.* 537-554. This article presents new empirical evidence indicating a deterministic component in the portfolio return dynamics of life-health and property-liability insurance company stocks. Our research is motivated by the fact that nonlinearities are a fact of economic life for many financial applications the source of which is logically apparent, yet empirical evidence of their existence is at best weak. The primary reason attributed to the weak findings of nonlinearities reported in previous research is the use of aggregate data that can hide nonlinearities at the micro level. Insurance sector stock returns are analysed because unique institutional characteristics indicate the possibility of identifying nonlinear dynamics. Tests based on the correlation dimension partially confirm the presence of nonlinearity. However, the more powerful Brock, Dechert, and Scheinkman (BDS) statistic strongly suggests the presence of nonlinearities in the insurance stock portfolio data. The BDS statistic applied to the standardized residuals of exponential generalized auto regressive conditional heteroskedasticity (EGARCH) models strongly rejects the null of independent and identically distributed, indicating that conditional heteroskedasticity is not responsible for the presence of the nonlinear structures in the data. In addition, tests for chaos based on locally weighted regressions indicate that insurance stock portfolio returns indicate low-complexity chaotic behaviour. This is an important result since most previous research has failed to report

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evidence of chaotic behaviour in the time series of stock returns. Important contributions of this article are the application of tests of nonlinearities and chaos to more desegregated data sets and the findings of statistically significant evidence indicating nonlinearities and low-deterministic chaotic behaviour in insurance stock portfolio returns.

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NORTH AMERICAN ACTUARIAL JOURNAL

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DE ALBA, E. *Bayesian estimation of outstanding claim reserves.* 1-20. This paper presents a Bayesian approach to forecasting outstanding claims, either the total number of claims or the total amount, that is used for claims reserving. The assumption is made that there is complete information for one or two past years of origin and partial information for some development years of other years of origin. It also assumes payments are made annually and that the development of partial payments follows a stable payoff pattern from one year of origin to another. Two different models are presented: one for the number of claims (intensity) and one for claim amounts (severity). The advantage of using this procedure is that actuaries can derive the complete predictive distribution of the reserve requirements, from which, in turn, it is possible to obtain point estimates as well as probability intervals and other summary measures, such as mean, variance, and quantiles.

LEMAIRE, J. *Why do females live longer than males?* 21-37. In most countries, females live several years longer than males. Many biological and behavioral reasons have been presented in the scientific literature to explain this 'female advantage'. A cross-sectional regression study, using 45 explanatory variables and data collected from 169 countries, provides support to the behavioral hypothesis. Four variables, unrelated to biological sex differences, explain over 61% of the variability of the life expectancy differential. One variable (the number of persons per physician) summarizes the degree of economic development of a country. The three other selected variables (the fertility rate, the percentage of Hindus and Buddhists, and Europeans countries of the former Soviet Union) are social/cultural/religious variables. This conclusion is slightly weakened when the presence of spatial autocorrelation in the date is specifically acknowledged.

MITCHELL, O. S. & MCCARTHY, D. *Estimating international adverse selection in annuities.* 38-54. It is well known that purchasers of annuities have lower mortality than the general population. Less widely known is the quantitative extent of this adverse selection and how it varies across countries. This paper proposes and applies several methods for comparing alternative mortality tables and illustrates their impact on annuity valuation for men and women in the U.S. and the U.K. Our results indicate that the relatively lower mortality among older Americans who purchase annuities is equivalent to using a discount rate that is 50-100 basis points below the U.K. rate for compulsory annuitants or 10-20 basis points lower than the U.K. rate for voluntary annuitants. We then draw on the mortality experience of over half a billion lives to estimate mortality differentials due varying degrees of adverse selection controlling for country, gender, and an allowance for mortality improvements. Results show that adverse selection associated with the purchase of individual annuities reduces mortality rates by at least 25% in the international context. We also find that the system of mortality tables used to value Japanese annuities is quite distinct from international norms.

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ROUDEBUSH, B. & KLEIN, J. *Converting clinical literature to an insured population: A comparison of models using NHANES.* 55-66. The use of clinical literature to set risk classification standards for life insurance underwriting stems from the need to set the most accurate standards using the best available information. A necessary hurdle in this process is converting any excess mortality observed in a clinical study to the appropriate rating for use in underwriting. A widely accepted model in the insurance industry, the Excess Death Rate model, treats the excess as additive to the conditional probability of death for an insurance company's unimpaired class.

In this paper we test the validity of that model versus other common predictive models of excess mortality in an insured population. Applying these models to National Health and Nutrition Examination Survey (NHANES) data, we derive estimates for excess mortality from three commonly seen underwriting impairments in what could be considered a clinical population.

The Excess Death Rate model performed the best of all models, having the smallest cumulative difference of actual to predicted deaths. The use of publicly available data, such as that in NHANES, could help bridge the gap between clinical literature and its application in insurance underwriting if insurable cohorts can be reliably identified from these generally healthy, ambulatory groups.

SCOLLNIK, D. *Regression models for bivariate loss data.* 67-80. This case study illustrates the analysis of two possible regression models for bivariate claims data. Estimates or forecasts of loss distributions under these two models are developed using two methods of analysis: (1) maximum likelihood estimation and (2) the Bayesian method. These methods are applied to two data sets consisting of 24 and 1500 paired observations, respectively. The Bayesian analyses are implemented using Markov chain Monte Carlo via WinBUGS, as discussed in Scollnik (2001). A comparison of the analyses reveals that forecasted total losses can be dramatically underestimated by the maximum likelihood estimation method because it ignores the inherent parameter uncertainty.

SEGAL, D. *An economic analysis of life insurance company expenses.* 81-94. This study provides an economic analysis of life insurance company expenses and develops a methodology for the construction of benchmark expense factors. These benchmarks can facilitate the pricing of new business, cost control within companies, and expense comparisons among companies. We derive the expense factors by estimating a cost function wherein total general expenses are modeled as a function of input prices and physical outputs, and the physical outputs are proxies for the cost drivers of the different lines of business. This methodology has two important advantages: first, the derived expense factors are independent of the methods that insurers use in allocating total expenses across lines of business. Second, the estimated cost function explicitly accounts for different degrees of economies of scale and consequently in the present value of marginal expenses across insurers. Hence, this study demonstrates that economies of scale and, in turn, size must be considered when constructing an expense table.

SERFLING, R. *Efficient and robust fitting of lognormal distributions.* 95-109. In parametric modelling of loss distributions in actuarial science, a versatile choice with intermediate tail weight is the lognormal distribution. Surprisingly, however, the fitting of this model using estimators that are at once efficient and robust has not been seriously addressed in the extensive literature. Consequently, typical estimators of the lognormal mean and variance fail to be both efficient and robust. In particular, the highly efficient maximum likelihood estimators lack robustness because of their limited sensitivity to outliers in the samples. For the two-parameter lognormal estimation problem, the author considers the problem of efficient and robust joint estimation of the mean and variance of a normal model. He introduces generalised-median-type estimators that yield efficient and robust estimators of

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various parameters of interest in the lognormal model. The paper provides detailed treatment of the lognormal mean and discusses extension of the approach to the much more complicated problem of estimation for the three-parameter lognormal model.

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