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ASTIN BULLETIN

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AFONSO, L. B., EGIDO DOS REIS, A. D. & WATERS, H. R. *Calculating continuous time ruin probabilities for a large portfolio with varying premiums.* 117-136. In this paper we present a method for the numerical evaluation of the ruin probability in continuous and finite time for a classical risk process where the premium can change from year to year. A major consideration in the development of this methodology is that it should be easily applicable to large portfolios. Our method is based on the simulation of the annual aggregate claims and then on the calculation of the ruin probability for a given surplus at the start and at the end of each year. We calculate the within-year ruin probability assuming a translated gamma distribution approximation for aggregate claim amounts. We illustrate our method by studying the case where the premium at the start of each year is a function of the surplus level at that time or at an earlier time.

ARTZNER, P., DELBAEN, F. & KOCH-MEDINA, P. *Risk measures and efficient use of capital.* 101-116. This paper is concerned with clarifying the link between risk measurement and capital efficiency. For this purpose we introduce risk measurement as the minimum cost of making a position acceptable by adding an optimal combination of multiple eligible assets. Under certain assumptions, it is shown that these risk measures have properties similar to those of coherent risk measures. The motivation for this paper was the study of a multi-currency setting where it is natural to use simultaneously a domestic and a foreign asset as investment vehicles to inject the capital necessary to make an unacceptable position acceptable. We also study what happens when one changes the unit of account from domestic to foreign currency and are led to the notion of compatibility of risk measures. In addition, we aim to clarify terminology in the field.

BUHLMANN, H., DE FELICE, M., GISLER, A., MORICONI, F. & WÜTHRICH, M. V. *Recursive credibility formula for chain ladder factors and the claims development result.* 275-306. In recent Solvency II considerations much effort has been put into the development of appropriate models for the study of the one-year loss reserving uncertainty in non-life insurance. In this article we derive formulas for the conditional mean square error of prediction of the one-year claims development result in the context of the Bayes chain ladder model studied in Gisler-Wüthrich [9]. The key to these formulas is a recursive representation for the results obtained in Gisler-Wüthrich [9].

CAI, J., FENG, R. & WILLMOT, G. E. *Analysis of the compound Poisson surplus model with liquid reserves, interest and dividends.* 225-247. The paper incorporates liquid reserves, interest and dividends in the compound Poisson surplus model. When an insurer's surplus is below a certain level, it is kept as liquid reserves. As the surplus attains the level, the excess of the surplus above the level will earn interest at a constant interest rate. If the surplus continues to surpass a higher level, the excess of the surplus above this higher level will be paid out as dividends to the insurer's shareholders at a constant dividend rate or by the threshold strategy. The lower and higher levels are called the liquid reserve level and the threshold level,

respectively. This paper is to discuss the interactions of the liquid reserve level, the interest rate, the threshold level, and the dividend rate in the proposed risk model by studying the expected discounted penalty function and the expected present value of dividends paid up to the time of ruin. We derive expressions for the solutions to both quantities via the approach of integro-differential equation systems. We show that the dividend-penalty identity (Gerber *et al.*, 2006, ASTIN Bulletin) still holds for the threshold strategy with liquid reserves and interest. We illustrate these results by deriving explicit solutions to the probability of ultimate ruin under the threshold strategy when claim sizes are exponentially distributed. In the end, we also discuss the impact of the liquid reserve level, the interest rate, the threshold level, and the dividend rate on the ruin probability by numerical examples.

FREES, E. W., SHI, P. S. & VALDEZ, E. A. *Actuarial applications of a hierarchical insurance claim model*. 165-197. This paper demonstrates actuarial applications of modern statistical methods that are applied to detailed, micro-level automobile insurance records. We consider 1993-2001 data consisting of policy and claims files from a major Singaporean insurance company. A hierarchical statistical model, developed in prior work (Frees and Valdez (2008)), is fit using the micro-level data. This model allows us to study the accident frequency, loss type and severity jointly and to incorporate individual characteristics such as age, gender and driving history that explain heterogeneity among policyholders. Based on this hierarchical model, one can analyze the risk profile of either a single policy (micro-level) or a portfolio of business (macro-level). This paper investigates three types of actuarial applications. First, we demonstrate the calculation of the predictive mean of losses for individual risk rating. This allows the actuary to differentiate prices based on policyholder characteristics. The nonlinear effects of coverage modifications such as deductibles, policy limits and coinsurance are quantified. Moreover, our flexible structure allows us to 'unbundle' contracts and price more primitive elements of the contract, such as coverage type. The second application concerns the predictive distribution of a portfolio of business. We demonstrate the calculation of various risk measures, including value at risk and conditional tail expectation, that are useful in determining economic capital for insurance companies. Third, we examine the effects of several reinsurance treaties. Specifically, we show the predictive loss distributions for both the insurer and reinsurer under quota share and excess-of-loss reinsurance agreements. In addition, we present an example of portfolio reinsurance, in which the combined effect of reinsurance agreements on the risk characteristics of ceding and reinsuring company are described.

GARRIDO, J. & ZHOU, J. *Full credibility with generalized linear and mixed models*. 61-80. Generalized linear models (GLMs) are gaining popularity as a statistical analysis method for insurance data. For segmented portfolios, as in car insurance, the question of credibility arises naturally; how many observations are needed in a risk class before the GLM estimators can be considered credible? In this paper we study the limited fluctuations credibility of the GLM estimators as well as in the extended case of generalized linear mixed model (GLMMs). We show how credibility depends on the sample size, the distribution of covariates and the link function. This provides a mechanism to obtain confidence intervals for the GLM and GLMM estimators.

HOSSJER, O., ERIKSSON, B., JARNMALM, K. & OHLSSON, E. *Assessing individual unexplained variation in non-life insurance*. 249-273. We consider variation of observed claim frequencies in non-life insurance, modeled by Poisson regression with overdispersion. In order to quantify how much variation between insurance policies that is captured by the rating factors, one may use the coefficient of determination, R^2 , the estimated proportion of total variation explained by the model. We introduce a novel coefficient of individual determination (CID), which excludes noise variance and is defined as the estimated fraction of total individual variation explained by the model. We argue that CID is a more relevant measure of explained variation than R^2 for data with Poisson variation. We also generalize previously used

estimates and tests of overdispersion and introduce new coefficients of individual explained and unexplained variance. Application to a Swedish three year motor TPL data set reveals that only 0.5% of the total variation and 11% of the total individual variation is explained by a model with seven rating factors, including interaction between sex and age. Even though the amount of overdispersion is small (4.4% of the noise variance) it is still highly significant. The coefficient of variation of explained and unexplained individual variation is 29% and 81% respectively.

HURLIMANN, W. *Credible loss ratio claims reserves: The Benktander, Neuhaus and Mack methods revisited.* 81-99. The Benktander (1976) and Neuhaus (1992) credibility claims reserving methods are reconsidered in the framework of a credible loss ratio reserving method. As a main contribution we provide a simple and practical optimal credibility weight for combining the chain-ladder or individual loss ratio reserve (grossed up latest claims experience of an origin period) with the Bornhuetter-Ferguson or collective loss ratio reserve (experience based burning cost estimate of the total ultimate claims of an origin period). The obtained simple optimal credibility weights minimize simultaneously the mean squared error and the variance of the claims reserve. We note also that the standard Chain-Ladder, Cape Cod and Bornhuetter-Ferguson methods can be reinterpreted in the credible context and extended to optimal credible standard methods. The new approach is inspired from Mack (2000). Two advantages over the Mack method are worthwhile to be mentioned. First, a pragmatic estimation of the required parameters leads to a straightforward calculation of the optimal credibility weights and mean squared errors of the credible reserves. An advantage of the collective loss ratio claims reserve over the Bornhuetter-Ferguson reserve in Mack (2000) is that different actuaries come always to the same results provided they use the same actuarial premiums.

KIM, J. H. T. & HARDY, M. R. *Estimating the variance of bootstrapped risk measures.* 199-223. In Kim and Hardy (2007) the exact bootstrap was used to estimate certain risk measures including Value at Risk and the Conditional Tail Expectation. In this paper we continue this work by deriving the influence function of the exact-bootstrapped quantile risk measure. We can use the influence function to estimate the variance of the exact-bootstrap risk measure. We then extend the result to the L-estimator class, which includes the conditional tail expectation risk measure. The resulting formula provides an alternative way to estimate the variance of the bootstrapped risk measures, or the whole L-estimator class in an analytic form. A simulation study shows that this new method is comparable to the ordinary resampling-based bootstrap method, with the advantages of an analytic approach.

LI, J. S.-H., HARDY, M. R & TAN, K. S. *Uncertainty in mortality forecasting: An extension to the classical Lee-Carter approach.* 137-164. Traditionally, actuaries have modeled mortality improvement using deterministic reduction factors, with little consideration of the associated uncertainty. As mortality improvement has become an increasingly significant source of financial risk, it has become important to measure the uncertainty in the forecasts. Probabilistic confidence intervals provided by the widely accepted Lee-Carter model are known to be excessively narrow, due primarily to the rigid structure of the model. In this paper, we relax the model structure by considering individual differences (heterogeneity) in each age-period cell. The proposed extension not only provides a better goodness-of-fit based on standard model selection criteria, but also ensures more conservative interval forecasts of central death rates and hence can better reflect the uncertainty entailed. We illustrate the results using US and Canadian mortality data.

LIU, H. & VERRALL, R. J. *Predictive distributions for reserves which separate true IBNR and IBNER claims.* 35-60. This paper considers the model suggested by Schnieper (1991), which separates the true IBNR claims from the IBNER. Stochastic models are defined, using both

recursive and non-recursive procedures, within the framework of the models described in England and Verrall (2002). Approximations to the prediction error of the reserves are derived analytically. Some extensions to the original Schnieper model are also discussed, together with other possible applications of this type of model.

MAHMOUDVAND, R. & HASSANI, H. *Generalized bonus-malus systems with a frequency and a severity component on an individual basis in automobile insurance*. 307-315. Frangos and Vrontos (2001) proposed an optimal bonus-malus systems with a frequency and a severity component on an individual basis in automobile insurance. In this paper, we introduce a generalized form of those obtained previously.

NIEDERAU, H. & ZWEIFEL, P. *Quasi risk-neutral pricing in insurance*. 317-337. This contribution shows that for certain classes of insurance risks, pricing can be based on expected values under a probability measure P^* amounting to quasi risk-neutral pricing. This probability measure is unique and optimal in the sense of minimizing the relative entropy with respect to the actuarial probability measure P , which is a common approach in the case of incomplete markets. After expounding the key elements of this theory, an application to a set of industrial property risks is developed, assuming that the severity of losses can be modeled by 'Swiss Re Exposure Curves', as discussed by Bernegger (1997). These curves belong to a parametric family of distribution functions commonly used by pricing actuaries. The quasi risk-neutral pricing approach not only yields risk exposure specific premiums but also Risk Adjusted Capital (RAC) values on the very same level of granularity. By way of contrast, the conventional determination of RAC is typically considered on a portfolio level only.

PETERS, G. W., SHEVCHENKO, P. V. & WÜTHRICH, M. V. *Model uncertainty in claims reserving within Tweedie's compound Poisson models*. 1-33. In this paper we examine the claims reserving problem using Tweedie's compound Poisson model. We develop the maximum likelihood and Bayesian Markov chain Monte Carlo simulation approaches to fit the model and then compare the estimated models under different scenarios. The key point we demonstrate relates to the comparison of reserving quantities with and without model uncertainty incorporated into the prediction. We consider both the model selection problem and the model averaging solutions for the predicted reserves. As a part of this process we also consider the sub problem of variable selection to obtain a parsimonious representation of the model being fitted.

THOMSON, R. J. & GOTT, D. V. *Stochastic models for actuarial use: The equilibrium modelling of local markets*. 339-370. In this paper, a long-term equilibrium model of a local market is developed. Subject to minor qualifications, the model is arbitrage-free. The variables modelled are the prices of risk-free zero-coupon bonds — both index-linked and conventional — and of equities, as well as the inflation rate. The model is developed in discrete (nominally annual) time, but allowance is made for processes in continuous time subject to continuous rebalancing. It is based on a model of the market portfolio comprising all the above-mentioned asset categories. The risk-free asset is taken to be the one-year index-linked bond. It is assumed that, conditionally upon information at the beginning of a year, market participants have homogeneous expectations with regard to the forthcoming year and make their decisions in mean-variance space. For the purposes of illustration, a descriptive version of the model is developed with reference to UK data. The parameters produced by that process may be used to inform the determination of those required for the use of the model as a predictive model. Illustrative results of simulations of the model are given.

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AUSTRALIAN ACTUARIAL JOURNAL

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ALCOCK, J. & HATHERLEY, A. *Asymmetric dependence between domestic equity indices and its effect on portfolio construction*. 143-180. We demonstrate a means of incorporating asymmetric dependency structures during the portfolio construction process using copula functions. Specifically, we investigate how asymmetric return dependencies affect the efficient frontier and subsequent portfolio performance under a dynamic rebalancing framework assuming normally distributed marginal returns. By considering the problem of tactically allocating a small set of domestic equity indices, we demonstrate several findings. First, we show that a Mean-Variance efficient frontier differs from the portfolios based upon these differences, we find that real economic value lies in correctly accounting for asymmetric correlation structures. The primary source of this economic value stems from the ability to better protect portfolio value and reduce the size of any erosion in return relative to the normal portfolio. Keywords: Portfolio selection, copula functions, conditional value-at-risk, asymmetric dependence.

THOMPSON, T. 2009 *Presidential Address: Colliding with the future*.

WU, X., WANG, J. & ZHOU, X. *Estimation of multi-stage survival distributions based on age-stage data*. 117-142. We study the problem of estimating the survival distributions of the times to enter different stages of a life based on survey data, which only indicate the ages of individuals and the stages they are in. Estimation procedures are developed using both nonparametric and parametric approaches, which are built on a fairly general ground. Nonparametric estimates are constructed based on data frequencies and their asymptotic properties are derived. A new parametric family of distributions is suggested to fit the data, which is found to match closely with the empirical survival function. Conditions on the parameters of the distribution family for maximum likelihood estimation are established. A computation procedure is proposed to obtain the estimates of the parameters for the multistage survival model. The estimation procedures are demonstrated through a case study involving a proposal of an aged-care fraternity in Shanghai, China. Keywords: multi-stage survival model, survival function, age-stage data, aged-care fraternity.

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GENEVA RISK AND INSURANCE REVIEW

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KRAWCZYK, M. *The role of repetition and observability in deterring insurance fraud*. 74-87. In this paper, I analyze an inspection game between an insurer and an infinite sequence of policyholders, who can try to misrepresent relevant information in order to obtain coverage or

lower insurance premium. Because claim-auditing is costly for the insurer, ex-post moral hazard problem arises. I find that the repeated game effect serves as a commitment device, allowing the insurer to deter fraud completely (for sufficiently high discount rate) but only when the policyholders observe past auditing strategies. Under weaker observability conditions, only partial efficiency gains are generally possible. I conclude that the insurers should spend resources on signaling their anti-fraud attempts to the potential policyholders. Similar conclusions can be drawn with respect to conceptually similar problems, such as tax evasion.

QUIGGIN, J. & CHAMBERS, R. G. *Bargaining power and efficiency in insurance contracts.* 47-73. Insurance contracts are frequently modelled as principal-agent relationships. The purpose of this paper is to examine the interaction between differential bargaining power and the efficiency of insurance contracts. The analysis is undertaken in a framework of state-contingent production, which allows us to consider, as separate choices, the level of effort committed by the client and the riskiness of the equilibrium state-contingent production vector. Our central result is that, in the presence of hold-up problems, the exercise of monopoly power by insurers leads clients to undertake socially costly self-protection, leading to suboptimal levels of insurance. Clients can exploit information asymmetries to offset the bargaining power of the insurer, but this process is also socially costly. Hence, competitive markets for insurance will yield a Pareto-superior outcome to the constrained Pareto-optimum reached in markets where insurers have monopoly power. More generally, in a bargaining situation, an increase in the bargaining power of clients will increase social welfare.

SONNENHOLZNER, M., FRIESE, S. & GRAF VON DER SCHULENBURG, J.-M. *Reinsurance brokers and advice quality: Is there a need for regulation?* 20-46. Brokers play an increasing role in the distribution of reinsurance. In order to analyse reinsurance brokers' advice quality, we employ a model in which a monopoly broker advises cedents to buy a particular one out of similar reinsurance policies that cost the same but differ in details. The broker decides on how much to invest in his advice quality and on the price to charge for his service. We find that the broker's advice quality is generally lower and the price for his service higher than in the social optimum, even in the presence of a potential new entrant.

WANG, K. C., HUANG, R. J. & TZENG, L. Y. *Empirical evidence for advantageous selection in the commercial fire insurance market.* 1-19. De Meza and Webb (2001) indicated that individuals with a higher degree of risk aversion would demand more insurance and invest in self-protection to reduce risk probability when both the preference type and investment in self-protection are hidden from insurers. They referred to the negative correlation between market insurance and risk type as advantageous selection. However, the relationship between risk type and the degree of risk aversion is debatable in both theoretical and empirical research. This paper therefore proposes that advantageous selection could be supported from another angle by directly examining the relationships that exist among market insurance, self-protection, and risk probability. By focusing on the commercial fire insurance market, information on the purchase of market insurance, investment in self-protection, and fire accident records is hand-collected by means of a unique survey. It is found that firms purchasing market insurance have a greater tendency to channel efforts into self-protection. It is also found that firms expending effort on self-protection are less likely to suffer a fire accident. Furthermore, it is found that firms with commercial fire insurance have less chance of suffering a fire accident than those without such insurance. Each of the above three findings jointly supports the view that advantageous selection could play a critical role in the commercial fire insurance market.

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AZCUE, P. & MULER, N. *Optimal investment strategy to minimize the ruin probability of an insurance company under borrowing constraints.* 26-34. We consider that the surplus of an insurance company follows a Cramér–Lundberg process. The management has the possibility of investing part of the surplus in a risky asset. We consider that the risky asset is a stock whose price process is a geometric Brownian motion. Our aim is to find a dynamic choice of the investment policy which minimizes the ruin probability of the company. We impose that the ratio between the amount invested in the risky asset and the surplus should be smaller than a given positive bound a . For instance the case $a = 1$ means that the management cannot borrow money to buy stocks. [Hipp, C., Plum, M., 2000. Optimal investment for insurers. *Insurance: Mathematics and Economics* 27, 215-228] and [Schmidli, H., 2002. On minimizing the ruin probability by investment and reinsurance. *Ann. Appl. Probab.* 12, 890-907] solved this problem without borrowing constraints. They found that the ratio between the amount invested in the risky asset and the surplus goes to infinity as the surplus approaches zero, so the optimal strategies of the constrained and unconstrained problems never coincide. We characterize the optimal value function as the classical solution of the associated Hamilton–Jacobi–Bellman equation. This equation is a second-order non-linear integro-differential equation. We obtain numerical solutions for some claim-size distributions and compare our results with those of the unconstrained case.

BAE, T., KIM, C. & KULPERGER, R. J. *Securitization of motor insurance loss rate risks.* 48-58. In an attempt to transfer the loss rate risks in motor insurance to the capital market, we use the tranche technique to hedge the motor insurance risks. This paper illustrates AXA and their securitization of French motor insurance in 2005 as an example. Though this application is new, this transaction is based on a concept similar to CDOs. Tranches of bonds are constructed on the basis of the expected loss ratio from motor insurance policy holders' groups. As a consequence we develop motor loss rate bonds using the structure of synthetic CDOs. The coupon payments of each tranche depend on the level of the loss rates of the underlying motor insurance pool. We show the integral formulas for the loss tranche contract where the loss distribution is modelled with discounted compound Poisson process. Esscher transform is chosen for a risk adjusted measure change and Fourier inversion method is used to calculate the price of the motor claim rate securities. The pricing methods of the tranches are illustrated, and possible suggestions to improve the pricing method and the design of these new securities follow.

BERMUDEZ, I. & MORATA, L. *A priori ratemaking using bivariate Poisson regression models.* 135-141. In automobile insurance, it is useful to achieve a priori ratemaking by resorting to generalized linear models, and here the Poisson regression model constitutes the most widely accepted basis. However, insurance companies distinguish between claims with or without bodily injuries, or claims with full or partial liability of the insured driver. This paper examines an a priori ratemaking procedure when including two different types of claim. When assuming independence between claim types, the premium can be obtained by summing the premiums for each type of guarantee and is dependent on the rating factors chosen. If the independence assumption is relaxed, then it is unclear as to how the tariff system might be affected. In order to answer this question, bivariate Poisson regression models, suitable for paired count data exhibiting correlation, are introduced. It is shown that the usual independence assumption is unrealistic here. These models are applied to an automobile insurance claims database containing 80,994 contracts belonging to a Spanish insurance company. Finally, the consequences for pure and loaded premiums when the independence assumption is relaxed by using a bivariate Poisson regression model are analysed.

CHANG, L.-F. & HUNG, M.-W. *Analytical valuation of catastrophe equity options with negative exponential jumps*. 59-69. A catastrophe put option is valuable in the event that the underlying asset price is below the strike price; in addition, a specified catastrophic event must have happened and influenced the insured company. This paper analyzes the valuation of catastrophe put options under deterministic and stochastic interest rates when the underlying asset price is modeled through a Lévy process with finite activity. We provide explicit analytical formulas for evaluating values of catastrophe put options. The numerical examples illustrate how financial risks and catastrophic risks affect the prices of catastrophe put options.

HATZOPOULOS, P. & HABERMAN, S. *A parameterized approach to modeling and forecasting mortality*. 103-123. A new method is proposed of constructing mortality forecasts. This parameterized approach utilizes Generalized Linear Models (GLMs), based on heteroscedastic Poisson (non-additive) error structures, and using an orthonormal polynomial design matrix. Principal Component (PC) analysis is then applied to the cross-sectional fitted parameters. The produced model can be viewed either as a one-factor parameterized model where the time series are the fitted parameters, or as a principal component model, namely a log-bilinear hierarchical statistical association model of Goodman [Goodman, L. A., 1991. Measures, models, and graphical displays in the analysis of cross-classified data. *J. Amer. Statist. Assoc.* **86** (416), 1085-1111] or equivalently as a generalized Lee-Carter model with p interaction terms. Mortality forecasts are obtained by applying dynamic linear regression models to the PCs. Two applications are presented: Sweden (1751-2006) and Greece (1957-2006).

HE, L. & LIANG, Z. *Optimal financing and dividend control of the insurance company with fixed and proportional transaction costs*. 88-94. We consider the optimal financing and dividend control problem of the insurance company with fixed and proportional transaction costs. The management of the company controls the reinsurance rate, dividends payout as well as the equity issuance process to maximize the expected present value of the dividends payout minus the equity issuance until the time of bankruptcy. This is the first time that the financing process in an insurance model with two kinds of transaction costs, which come from real financial market has been considered. We solve the mixed classical-impulse control problem by constructing two categories of suboptimal models, one is the classical model without equity issuance, the other never goes bankrupt by equity issuance.

KLEINOW, T. *Valuation and hedging of participating life-insurance policies under management discretion*. 78-87. The valuation and hedging of participating life insurance policies, also known as with-profits policies, is considered. Such policies can be seen as European path-dependent contingent claims whose underlying security is the investment portfolio of the insurance company that sold the policy. The fair valuation of these policies is studied under the assumption that the insurance company has the right to modify the investment strategy of the underlying portfolio at any time. Furthermore, it is assumed that the issuer of the policy does not setup a separate portfolio to hedge the risk associated with the policy. Instead, the issuer will use its discretion about the investment strategy of the underlying portfolio to hedge shortfall risks. In that sense, the insurer's investment portfolio serves simultaneously as the underlying security and as the hedge portfolio. This means that the hedging problem can not be separated from the valuation problem. We investigate the relationship between risk-neutral valuation and hedging of these policies in complete and incomplete financial markets.

LAURENCE, P. & WANG, T.-H. *Sharp distribution free lower bounds for spread options and the corresponding optimal subreplicating portfolios*. 35-47. We derive in closed form distribution free lower bounds and optimal subreplicating strategies for spread options in a one-period static arbitrage setting. In the case of a continuum of strikes, we complement the optimal lower bound for spread options obtained in [Rapuch, G., Roncalli, T., 2002. Pricing multiasset

options and credit derivatives with copula, Credit Lyonnais, Working Papers] by describing its corresponding subreplicating strategy. This result is explored numerically in a Black–Scholes and in a CEV setting. In the case of discrete strikes, we solve in closed form the optimization problem in which, for each asset S1 and S2, forward prices and the price of one option are used as constraints on the marginal distributions of each asset. We provide a partial solution in the case where the marginal distributions are constrained by two strikes per asset. Numerical results on real NYMEX (New York Mercantile Exchange) crack spread option data show that the one discrete lower bound can be far and also very close to the traded price. In addition, the one strike closed form solution is very close to the two strike.

MOORE, K. S. *Optimal surrender strategies for equity-indexed annuity investors.* 1-18. An equity-indexed annuity (EIA) is a hybrid between a variable and a fixed annuity that allows the investor to participate in the stock market, and earn at least a minimum interest rate. The investor sacrifices some of the upside potential for the downside protection of the minimum guarantee. Because EIAs allow investors to participate in equity growth without the downside risk, their popularity has grown rapidly. An optimistic EIA owner might consider surrendering an EIA contract, paying a surrender charge, and investing the proceeds directly in the index to earn the full (versus reduced) index growth, while using a risk-free account for downside protection. Because of the popularity of these products, it is important for individuals and insurers to understand the optimal policyholder behavior. We consider an EIA investor who seeks the surrender strategy and post-surrender asset allocation strategy that maximizes the expected discounted utility of bequest. We formulate a variational inequality and a Hamilton–Jacobi–Bellman equation that govern the optimal surrender strategy and post-surrender asset allocation strategy, respectively. We examine the optimal strategies and how they are affected by the product features, model parameters, and mortality assumptions. We observe that in many cases, the “no-surrender” region is an interval (wl, wu) ; i.e. that there are two free boundaries. In these cases, the investor surrenders the EIA contract if the fund value becomes too high or too low. In other cases, there is only one free boundary; the lower (or upper) surrender threshold vanishes. In these cases, the investor holds the EIA, regardless of how low (or high) the fund value goes. For a special case, we prove a succinct and intuitive condition on the model parameters that dictates whether one or two free boundaries exist.

PLAT, R. & PELSSER, A. *Analytical approximations for prices of swap rate dependent embedded options in insurance products.* 124-134. Life insurance products have profit sharing features in combination with guarantees. These so-called embedded options are often dependent on or approximated by forward swap rates. In practice, these kinds of options are mostly valued by Monte Carlo simulations. However, for risk management calculations and reporting processes, lots of valuations are needed. Therefore, a more efficient method to value these options would be helpful. In this paper analytical approximations are derived for these kinds of options, based on an underlying multi-factor Gaussian interest rate model. The analytical approximation for options with direct payment is almost exact while the approximation for compounding options is also satisfactory. In addition, the proposed analytical approximation can be used as a control variate in Monte Carlo valuation of options for which no analytical approximation is available, such as similar options with management actions. Furthermore, it's also possible to construct analytical approximations when returns on additional assets (such as equities) are part of the profit sharing rate.

SHIMIZU, Y. *A new aspect of a risk process and its statistical inference.* 70-77. We introduce a new aspect of a risk process, which is a macro approximation of the flow of a risk reserve. We assume that the underlying process consists of a Brownian motion plus negative jumps, and that the process is observed at discrete time points. In our context, each jump size of the process does not necessarily correspond to the each claim size. Therefore our risk process is different from the traditional risk process. We cannot directly observe each jump size because

of discrete observations. Our goal is to estimate the adjustment coefficient of our risk process from discrete observations.

WEN, L., WU, Z. & ZHOU, X. *The credibility premiums for models with dependence induced by common effects*. 19-25. In classical Bühlmann credibility models, claims are assumed to be independent between different risks. In many practical situations, however, this assumption may be violated because there are situations that could drive possible relationship among the insured individuals. This paper aims to extend the Bühlmann and Bühlmann–Straub credibility models to account for a special type of dependence between risks induced by common stochastic effects. By means of the projection method, the corresponding credibility premiums are obtained, which generalize some well known existing results in credibility theory.

WU, Y.-C., LIAO, S.-L. & SHYU, S.-D. *Closed-form valuations of basket options using a multivariate normal inverse Gaussian model*. 95-102. This paper uses a multivariate normal inverse Gaussian model to develop closed-form pricing formulas for both geometric and arithmetic basket options. For geometric basket options, an exact analytical solution is possible; for arithmetic basket options, the formula is an approximation. The model is based on a jump-driven financial process, which is known empirically to be more realistic than a geometric Brownian motion. By comparing our results to Monte Carlo experiments, we confirm the internal consistency of our formulas. The “Greeks” can be derived from the closed-form formulas in a straightforward manner.

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AAS, K., CZADO, C., FRIGESSI, A. & BAKKEN, H. *Pair-copula constructions of multiple dependence*. 182-198. Building on the work of Bedford, Cooke and Joe, we show how multivariate data, which exhibit complex patterns of dependence in the tails, can be modelled using a cascade of pair-copulae, acting on two variables at a time. We use the pair-copula decomposition of a general multivariate distribution and propose a method for performing inference. The model construction is hierarchical in nature, the various levels corresponding to the incorporation of more variables in the conditioning sets, using pair-copulae as simple building blocks. Pair-copula decomposed models also represent a very flexible way to construct higher-dimensional copulae. We apply the methodology to a financial data set. Our approach represents the first step towards the development of an unsupervised algorithm that explores the space of possible pair-copula models, that also can be applied to huge data sets automatically.

ALBRECHER, H., BORST, S., BOXMA, O. & RESING, J. *The tax identity in risk theory — a simple proof and an extension*. 304-306. By linking queueing concepts with risk theory, we give a simple and insightful proof of the tax identity in the Cramér–Lundberg model that was recently derived in Albrecher & Hipp [Albrecher, H., Hipp, C., 2007. Lundberg’s risk process with tax. *Blätter der DGVFM* 28 (1), 13-28], and extend the identity to arbitrary surplus-dependent tax rates.

CHADJICONSTANTINIDIS, S. & PITSELIS, G. *Further improved recursions for a class of compound Poisson distributions*. 278-286. In the present paper we develop more efficient recursive formulae for the evaluation of the t -order cumulative function $G_{th}(x)$ and the t -order tail probability $th(x)$ of the class of compound Poisson distributions in the case where the derivative of the probability generating function of the claim amounts can be written as a ratio of two polynomials. These efficient recursions can be applied for the exact evaluation of the

probability function (given by De Pril [De Pril, N., 1986a. Improved recursions for some compound Poisson distributions. *Insurance Math. Econom.* **5**, 129-132]), distribution function, tail probability, stop-loss premiums and t -order moments of stop-loss transforms of compound Poisson distributions. Also, efficient recursive algorithms are given for the evaluation of higher-order moments and r -order factorial moments about any point for this class of compound Poisson distributions. Finally, several examples of discrete claim size distributions belonging to this class are also given.

EMBRECHTS, P., NESLEHOVA, J. & WÜTHRICH, M. V. *Additivity properties for Value-at-Risk under Archimedean dependence and heavy-tailedness.* 164-169. Mainly due to new capital adequacy standards for banking and insurance, an increased interest exists in the aggregation properties of risk measures like Value-at-Risk (VaR). We show how VaR can change from sub to superadditivity depending on the properties of the underlying model. Mainly, the switch from a finite to an infinite mean model gives a completely different asymptotic behaviour. Our main result proves a conjecture made in Barbe *et al.* [Barbe, P., Fougères, A. L., Genest, C., 2006. On the tail behavior of sums of dependent risks. *ASTIN Bull.* **36** (2), 361-374].

GENEST, C., MASIELLO, E. & TRIBOULEY, K. *Estimating copula densities through wavelets.* 170-181. Wavelet analysis is used to construct a rank-based estimator of a copula density. The procedure, which can be easily implemented with ready-to-use wavelet packages, is based on an algorithm that handles boundary effects automatically. The resulting estimator provides a non-parametric benchmark for the selection of a parametric copula family. From a theoretical point of view, the estimation procedure is shown to be optimal in the minimax sense on a large functional class of regular copula densities. The approach is illustrated with actuarial and financial data.

GENEST, C., REMILLARD, B. & BEAUDOIN, D. *Goodness-of-fit test for copulas: a review and a power study.* 199-213. Many proposals have been made recently for goodness-of-fit testing of copula models. After reviewing them briefly, the authors concentrate on "blanket tests", i.e. those whose implementation requires neither an arbitrary categorization of the data nor any strategic choice of smoothing parameter, weight function, kernel, window, etc. The authors present a critical review of these procedures and suggest new ones. They describe and interpret the results of a large Monte Carlo experiment designed to assess the effect of the sample size and the strength of dependence on the level and power of the blanket tests for various combinations of copula models under the null hypothesis and the alternative. To circumvent problems in the determination of the limiting distribution of the test statistics under composite null hypotheses, they recommend the use of a double parametric bootstrap procedure, whose implementation is detailed. They conclude with a number of practical recommendations.

KAAS, R., LAEVEN, R. J. A. & NELSEN, R. B. *Worst VaR scenarios with given marginals and measures of association.* 146-158. This paper studies the problem of finding best-possible upper bounds on the Value-at-Risk for a function of two random variables when the marginal distributions are known and additional nonparametric information on the dependence structure, such as the value of a measure of association, is available. The same problem for the Tail-Value-at-Risk is also briefly discussed.

LAEVEN, R. J. A. *Worst VaR scenarios: a remark.* 159-163. Theorem 15 of Embrechts *et al.* [Embrechts, Paul, Höing, Andrea, Puccetti, Giovanni, 2005. Worst VaR scenarios. *Insurance: Math. Econom.* **37**, 115-134] proves that comonotonicity gives rise to the on-average-most-adverse Value-at-Risk scenario for a function of dependent risks, when the marginal distributions are known but the dependence structure between the risks is unknown. This note extends this result to the case where, rather than no information, partial information is available on the dependence structure between the risks. A result of Kaas *et al.* [Kaas, Rob,

Dhaene, Jan, Goovaerts, Marc, J., 2000. Upper and lower bounds for sums of random variables. *Insurance: Math. Econom.* **23**, 151-168] is also generalized for this purpose.

LIN, X. S. & WANG, T. *Pricing perpetual American catastrophe put options: a penalty function approach.* 287-295. The expected discounted penalty function proposed in the seminal paper by Gerber and Shiu [Gerber, H. U., Shiu, E. S. W., 1998. On the time value of ruin. *North Amer. Actuarial J.* **2** (1), 48-78] has been widely used to analyze the joint distribution of the time of ruin, the surplus immediately before ruin and the deficit at ruin, and the related quantities in ruin theory. However, few of its applications can be found beyond except that Gerber and Landry [Gerber, H. U., Landry, B., 1998. On the discount penalty at ruin in a jump-diffusion and the perpetual put option. *Insurance: Math. Econ.* **22**, 263-276] explored its use for the pricing of perpetual American put options. In this paper, we further explore the use of the expected discounted penalty function and mathematical tools developed for the function to evaluate perpetual American catastrophe equity put options. We obtain the analytical expression for the price of perpetual American catastrophe equity put options and conduct a numerical implementation for a wide range of parameter values. We show that the use of the expected discounted penalty function enables us to evaluate the perpetual American catastrophe equity put option with minimal numerical work.

LU, Y. & LI, S. *The Markovian regime-switching risk model with a threshold dividend strategy.* 296-303. In this paper, we study a regime-switching risk model with a threshold dividend strategy, in which the rate for the Poisson claim arrivals and the distribution of the claim amounts are driven by an underlying (external) Markov jump process. The purpose of this paper is to study the unified Gerber–Shiu discounted penalty function and the moments of the total dividend payments until ruin. We adopt an approach which is akin to the one used in [Lin, X. S., Pavlova, K. P., 2006. The compound Poisson risk model with a threshold dividend strategy. *Insu.: Math. and Econ.* **38**, 57-80] to extend the results for the classical risk model with a threshold dividend strategy to our model. The matrix form of systems of integro-differential equations is presented and the analytical solutions to these systems are derived. Finally, numerical illustrations with exponential claim amounts are also given.

MARCEAU, E. *On the discrete-time compound renewal risk model with dependence.* 245-259. In this paper, we study the discrete-time renewal risk model with dependence between the claim amount random variable and the interclaim time random variable. We consider several dependence structures between the claim amount random variable and the interclaim time random variable. Recursive formulas are derived for the probability mass function and the moments of the total claim amount over a fixed period of time. In the context of ruin theory, explicit expressions for the expected penalty (Gerber–Shiu) function are derived for special cases. We also discuss how the discrete-time compound renewal risk model with dependence can be used to approximate the corresponding continuous time compound renewal risk model with dependence. Numerical examples are provided to illustrate different topics discussed in the paper.

NG, A. C. Y. *On a dual model with a dividend threshold.* 315-324. In insurance mathematics, a compound Poisson model is often used to describe the aggregate claims of the surplus process. In this paper, we consider the dual of the compound Poisson model under a threshold dividend strategy. We derive a set of two integro-differential equations satisfied by the expected total discounted dividends until ruin and show how the equations can be solved by using only one of the two integro-differential equations. The cases where profits follow an exponential or a mixture of exponential distributions are then solved and the discussion for the case of a general profit distribution follows by the use of Laplace transforms. We illustrate how the optimal threshold level that maximizes the expected total discounted dividends until ruin can be obtained, and finally we generalize the results to the case where the surplus process is a more general skip-free downwards Lévy process.

SCHMIDT, R. & SCHMIEDER, C. *Modelling dynamic portfolio risk using risk drivers of elliptical processes*. 229-244. The situation of a limited availability of historical data is frequently encountered in portfolio risk estimation, especially in credit risk estimation. This makes it difficult, for example, to find statistically significant temporal structures in the data on the single asset level. By contrast, there is often a broader availability of cross-sectional data, i.e. a large number of assets in the portfolio. This paper proposes a stochastic dynamic model which takes this situation into account. The modelling framework is based on multivariate elliptical processes which model portfolio risk via sub-portfolio specific volatility indices called portfolio risk drivers. The dynamics of the risk drivers are modelled by multiplicative error models (MEMs) — as introduced by Engle [Engle, R. F., 2002. New frontiers for ARCH models. *J. Appl. Econom.* **17**, 425-446] — or by traditional ARMA models. The model is calibrated to Moody's KMV Credit Monitor asset returns (also known as firm-value returns) given on a monthly basis for 756 listed European companies at 115 time points from 1996 to 2005. This database is used by financial institutions to assess the credit quality of firms. The proposed risk drivers capture the volatility structure of asset returns in different industry sectors. A characteristic cyclical as well as a seasonal temporal structure of the risk drivers is found across all industry sectors. In addition, each risk driver exhibits idiosyncratic developments. We also identify correlations between the risk drivers and selected macroeconomic variables. These findings may improve the estimation of risk measures such as the (portfolio) Value at Risk. The proposed methods are general and can be applied to any series of multivariate asset or equity returns in finance and insurance.

SHAPIRO, A. F. *Fuzzy random variables*. 307-314. There are two important sources of uncertainty: randomness and fuzziness. Randomness models the stochastic variability of all possible outcomes of a situation, and fuzziness relates to the unsharp boundaries of the parameters of the model. In this sense, randomness is largely an instrument of a normative analysis that focuses on the future, while fuzziness is more an instrument of a descriptive analysis reflecting the past and its implications. Clearly, randomness and fuzziness are complementary, and so a natural question is how fuzzy variables could interact with the type of random variables found in actuarial science. This article focuses on one important dimension of this issue, fuzzy random variables (FRVs). The goal is to introduce IME readers to FRVs and to illustrate how naturally compatible and complementary randomness and fuzziness are.

TSANAKAS, A. *To split or not to split: Capital allocation with convex risk measures*. 268-277. Convex risk measures were introduced by Deprez and Gerber [Deprez, O., Gerber, H. U., 1985. On convex principles of premium calculation. *Insurance: Math. Econom.* **4** (3), 179-189]. Here the problem of allocating risk capital to subportfolios is addressed, when convex risk measures are used. The Aumann-Shapley value is proposed as an appropriate allocation mechanism. Distortion-exponential measures are discussed extensively and explicit capital allocation formulas are obtained for the case that the risk measure belongs to this family. Finally the implications of capital allocation with a convex risk measure for the stability of portfolios are discussed. It is demonstrated that using a convex risk measure for capital allocation can produce an incentive for infinite fragmentation of portfolios.

YOUNG, G., VALEZ, E. A. & KOHN, R. *Multivariate profit models for conditional claim-types*. 214-228. This paper considers statistical modeling of the types of claim in a portfolio of insurance policies. For some classes of insurance contracts, in a particular period, it is possible to have a record of whether or not there is a claim on the policy, the types of claims made on the policy, and the amount of claims arising from each of the types. A typical example is automobile insurance where in the event of a claim, we are able to observe the amounts that arise from say injury to oneself, damage to one's own property, damage to a third party's property, and injury to a third party. Modeling the frequency and the severity components of the claims can be handled using traditional actuarial procedures. However, modeling the

claim-type component is less known and in this paper, we recommend analyzing the distribution of these claim-types using multivariate probit models, which can be viewed as latent variable threshold models for the analysis of multivariate binary data. A recent article by Valdez and Frees [Valdez, E. A., Frees, E. W., Longitudinal modeling of Singapore motor insurance. University of New South Wales and the University of Wisconsin-Madison. Working Paper. Dated 28 December 2005, available from: <http://www.docs.fce.unsw.edu.au/actuarial/research/papers/2006/Valdez-Frees-2005.pdf>] considered this decomposition to extend the traditional model by including the conditional claim-type component, and proposed the multinomial logit model to empirically estimate this component. However, it is well known in the literature that this type of model assumes independence across the different outcomes. We investigate the appropriateness of fitting a multivariate probit model to the conditional claim-type component in which the outcomes may in fact be correlated, with possible inclusion of important covariates. Our estimation results show that when the outcomes are correlated, the multinomial logit model produces substantially different predictions relative to the true predictions; and second, through a simulation analysis, we find that even in ideal conditions under which the outcomes are independent, multinomial logit is still a poor approximation to the true underlying outcome probabilities relative to the multivariate probit model. The results of this paper serve to highlight the trade-off between tractability and flexibility when choosing the appropriate model.

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ACCACIO, B. & SVINDLAND, G. *Optimal risk sharing with different reference probabilities.* 426-433. We investigate the problem of optimal risk sharing between agents endowed with cash-invariant choice functions which are law-invariant with respect to different reference probability measures. We motivate a discrete setting both from an operational and a theoretical point of view, and give sufficient conditions for the existence of Pareto optimal allocations in this framework. Our results are illustrated by several examples.

AMBAGASPITIYA, R. *Ultimate ruin probability in the Sparre Andersen model with dependent claim sizes and claim occurrence times.* 464-472. In this paper we relax the independence assumption of claim sizes and claim occurrence times in the Sparre Andersen model. We consider two different classes of bivariate distributions to model claim occurrence and claim sizes. We obtain explicit expressions for the ultimate ruin probability using the well known Wiener-Hopf factorization.

BALBAS, A., BALBAS, B. & HERAS, A. *Optimal reinsurance with general risk measures.* 374-384. This paper studies the optimal reinsurance problem when risk is measured by a general risk measure. Necessary and sufficient optimality conditions are given for a wide family of risk measures, including deviation measures, expectation bounded risk measures and coherent measures of risk. The optimality conditions are used to verify whether the classical reinsurance contracts (quota-share, stop-loss) are optimal essentially, regardless of the risk measure used. The paper ends by particularizing the findings, so as to study in detail two deviation measures and the conditional value at risk.

BAYRAKTAR, E. & YOUNG, V. R. *Minimizing the lifetime shortfall or shortfall at death.* 447-458. We find the optimal investment strategy for an individual who seeks to minimize one of four objectives: (1) the probability that his/her wealth reaches a specified ruin level before death, (2) the probability that his/her wealth reaches that level at death, (3) the expectation of how low his/her wealth drops below a specified level before death, and (4) the expectation of

how low his/her wealth drops below a specified level at death. Young [Young, V. R., 2004. Optimal investment strategy to minimize the probability of lifetime ruin. *N. Am. Actua. J.* **8** (4), 105-126] showed that under criterion (1), the optimal investment strategy is a heavily leveraged position in the risky asset for low wealth. In this paper, we introduce the other three criteria in order to reduce the leveraging observed by Young, the above mentioned reference. We discovered that surprisingly the optimal investment strategy for criterion (3) is identical to the one for (1) and that the strategies for (2) and (4) are more leveraged than the one for (1) at low wealth. Because these criteria do not reduce leveraging, we completely remove it by considering problems (1) and (3) under the restriction that the individual cannot borrow to invest in the risky asset.

BRODIN, E. & ROOTZEN, H. *Univariate and bivariate GPD methods for predicting extreme wind storm losses.* 345-356. Wind storm and hurricane risks are attracting increased attention as a result of recent catastrophic events. The aim of this paper is to select, tailor, and develop extreme value methods for use in wind storm insurance. The methods are applied to the 1982-2005 losses for the largest Swedish insurance company, the Länsförsäkringar group. Both a univariate and a new bivariate Generalized Pareto Distribution (GPD) gave models which fitted the data well. The bivariate model led to lower estimates of risk, except for extreme cases, but taking statistical uncertainty into account the two models lead to qualitatively similar results. We believe that the bivariate model provided the most realistic picture of the real uncertainties. It additionally made it possible to explore the effects of changes in the insurance portfolio, and showed that loss distributions are rather insensitive to portfolio changes. We found a small trend in the sizes of small individual claims, but no other trends. Finally, we believe that companies should develop systematic ways of thinking about “not yet seen” disasters.

CHI, Y., YANG, J. & QI, Y. *Decomposition of a Schur-constant model and its applications.* 398-408. In this paper, the dependence structure of a Schur-constant model is investigated. A necessary and sufficient condition for a random vector to be Schur-constant is given, and some properties of the Schur-constant model are presented as well. Several applications of the Schur-constant model in insurance and finance are discussed.

DANG, L., ZHU, N. & ZHANG, H. *Survival probability for a two-dimensional risk model.* 491-496. In this paper, we consider the survival probability for a two-dimensional risk model. We derive a partial integro-differential equation satisfied by the survival probability and prove its differentiability. We obtain explicit expressions for recursively calculating the survival probability by applying the partial integro-differential equation when claims are exponentially distributed.

GAO, F., POWERS, M. R. & WANG, J. *Adverse selection or advantageous selection?: Risk and underwriting in China's health-insurance market.* 505-510. Using data from China's individual health-insurance market, we study the problem of information asymmetry. Our preliminary results appear to contradict standard-model predictions, showing that higher-risk buyers are more likely to purchase “additional” insurance than lower-risk buyers, but that they also tend to purchase lower limits of “basic” insurance coverage. We therefore develop a theoretical model to capture the effects of buyers' wealth levels and loss amounts, and show empirically that these effects, in the context of asymmetric information, lead to the coexistence of adverse selection and advantageous selection in China's health-insurance market.

GAO, J. *Optimal portfolios for DC pension plans under a CEV model.* 479-490. This paper studies the portfolio optimization problem for an investor who seeks to maximize the expected utility of the terminal wealth in a DC pension plan. We focus on a constant elasticity of variance (CEV) model to describe the stock price dynamics, which is an extension of geometric

Brownian motion. By applying stochastic optimal control, power transform and variable change technique, we derive the explicit solutions for the CRRA and CARA utility functions, respectively. Each solution consists of a moving Merton strategy and a correction factor. The moving Merton strategy is similar to the result of Devolder *et al.* [Devolder, P., Bosch, P. M., Dominguez F. I., 2003. Stochastic optimal control of annuity contracts. *Insurance: Math. Econom.* **33**, 227-238], whereas it has an updated instantaneous volatility at the current time. The correction factor denotes a supplement term to hedge the volatility risk. In order to have a better understanding of the impact of the correction factor on the optimal strategy, we analyze the property of the correction factor. Finally, we present a numerical simulation to illustrate the properties and sensitivities of the correction factor and the optimal strategy.

GERSTNER, T., GRIEBEL, M. & HOLTZ, M. *Efficient deterministic numerical simulation of stochastic asset-liability management models in life insurance.* 434-446. New regulations, stronger competitions and more volatile capital markets have increased the demand for stochastic asset-liability management (ALM) models for insurance companies in recent years. The numerical simulation of such models is usually performed by Monte Carlo methods which suffer from a slow and erratic convergence, though. As alternatives to Monte Carlo simulation, we propose and investigate in this article the use of deterministic integration schemes, such as quasi-Monte Carlo and sparse grid quadrature methods. Numerical experiments with different ALM models for portfolios of participating life insurance products demonstrate that these deterministic methods often converge faster, are less erratic and produce more accurate results than Monte Carlo simulation even for small sample sizes and complex models if the methods are combined with adaptivity and dimension reduction techniques. In addition, we show by an analysis of variance (ANOVA) that ALM problems are often of very low effective dimension which provides a theoretical explanation for the success of the deterministic quadrature methods.

HESS, C. *Computing the mean and the variance of the cedent's share for largest claims reinsurance covers.* 497-504. We present mathematical results allowing one to evaluate the moments of order 1 and 2 of the cedent's share in the framework of reinsurance treaties based on ordered claim sizes. These results consist of closed analytical formulas that do not involve any approximation procedure. This is illustrated by numerical examples when the claim number has the Poisson or the negative binomial distribution, and the claim cost has the exponential or the Pareto distribution.

KIM, J. H. T. & HARDY, M. R. *A capital allocation based on a solvency exchange option.* 357-366. In this paper we propose a new capital allocation method based on an idea of [Sherris, M., 2006. Solvency, capital allocation and fair rate of return in insurance. *J. Risk Insurance* **73** (1), 71-96]. The proposed method explicitly accommodates the notion of limited liability of the shareholders. We show how the allocated capital can be decomposed, so that each stakeholder can have a clearer understanding of their contribution. We also challenge the no undercut principle, one of the widely accepted allocation axioms, and assert that this axiom is merely a property that certain allocation methods may or may not meet.

SADEFO KAMDEM, J. *-VaR and -TVaR for portfolios with mixture of elliptic distributions risk factors and DCC.* 325-336. This paper generalizes the -VaR and -TVaR method from portfolios with normally distributed risk factors to portfolios with mixture of elliptically distributed ones, when the volatility is governed by an elliptic MGARCH. Special attention is given to the particular case of a mixture of multivariate *t*-distributions with the elliptic dynamic conditional correlation (E-DCC).

SHEREMET, O. & LUCAS, A. *Global loss diversification in the insurance sector.* 415-425. We study the possibility for international diversification of catastrophe risk by the insurance sector.

Adopting the argument that large insurance losses may be a 'globalizing factor' for the industry, we study the dependence of geographically distant insurance markets via equity returns. In particular, we employ conditional copula theory to model the bivariate dependence of the insurance industry. In contrast to earlier literature on this subject, we disentangle the causes of dependence stemming from the asset side from those from the liability side by conditioning on general market conditions. We find that for both Europe–America and Europe–Asia the dependence is significant. Moreover, we find asymmetric effects: the international dependence is particularly high for losses, even after conditioning for the asset side dependence. Finally, we investigate the time variation in copula parameters and find evidence that dependence in the insurance sector has increased over time, thus reducing the scope for international diversification of large losses in this sector.

- VALDEZ, E. A., DHAENE, J., MAJ, M. & VANDUFFEL, S. *Bounds and approximations for sums of dependent log-elliptical random variables*. 385-397. Dhaene, Denuit, Goovaerts, Kaas and Vyncke [Dhaene, J., Denuit, M., Goovaerts, M. J., Kaas, R., Vyncke, D., 2002a. The concept of comonotonicity in actuarial science and finance: theory. *Insurance Math. Econom.* **31** (1), 3-33; Dhaene, J., Denuit, M., Goovaerts, M. J., Kaas, R., Vyncke, D., 2002b. The concept of comonotonicity in actuarial science and finance: Applications. *Insurance Math. Econom.* **31** (2), 133-161] have studied convex bounds for a sum of dependent random variables and applied these to sums of log-normal random variables. In particular, they have shown how these convex bounds can be used to derive closed-form approximations for several of the risk measures of such a sum. In this paper we investigate to which extent their general results on convex bounds can also be applied to sums of log-elliptical random variables which incorporate sums of log-normals as a special case. Firstly, we show that unlike the log-normal case, for general sums of log-ellipticals the convex lower bound does no longer result in closed-form approximations for the different risk measures. Secondly, we demonstrate how instead the weaker stop-loss order can be used to derive such closed-form approximations. We also present numerical examples to show the accuracy of the proposed approximations.
- VALLOIS, P. & TAPIERO, C. S. *A claims persistence process and insurance*. 367-373. The purpose of this paper is to introduce and construct a state dependent counting and persistent random walk. Persistence is embedded in a Markov chain for predicting insured claims based on their current and past period claim. We calculate for such a process, the probability generating function of the number of claims over time and as a result are able to calculate their moments. Further, given the claims severity probability distribution, we provide both the claims process generating function as well as the mean and the claim variance that an insurance firm confronts over a given period of time and in such circumstances. A number of results and applications are then outlined (such as a Compound Claim Persistence Process).
- XU, W., WU, C., XU, W. & LI, H. *A jump-diffusion model for option pricing under fuzzy environments*. 337-344. Owing to fluctuations in the financial markets from time to time, the rate of Poisson process and jump sequence $\{V_i\}$ in the Merton's normal jump-diffusion model cannot be expected in a precise sense. Therefore, the fuzzy set theory proposed by Zadeh [Zadeh, L. A., 1965. Fuzzy sets. *Inform. Control* **8**, 338-353] and the fuzzy random variable introduced by Kwakernaak [Kwakernaak, H., 1978. Fuzzy random variables I: Definitions and theorems. *Inform. Sci.* **15**, 1-29] and Puri and Ralescu [Puri, M. L., Ralescu, D. A., 1986. Fuzzy random variables. *J. Math. Anal. Appl.* **114**, 409-422] may be useful for modeling this kind of imprecise problem. In this paper, probability is applied to characterize the uncertainty as to whether jumps occur or not, and what the amplitudes are, while fuzziness is applied to characterize the uncertainty related to the exact number of jump times and the jump amplitudes, due to a lack of knowledge regarding financial markets. This paper presents a fuzzy normal jump-diffusion model for European option pricing, with uncertainty of both randomness and fuzziness in the jumps, which is a reasonable and a natural extension of

the Merton [Merton, R. C., 1976. Option pricing when underlying stock returns are discontinuous. *J. Financ. Econ.* 3, 125-144] normal jump-diffusion model. Based on the crisp weighted possibilistic mean values of the fuzzy variables in fuzzy normal jump-diffusion model, we also obtain the crisp weighted possibilistic mean normal jump-diffusion model. Numerical analysis shows that the fuzzy normal jump-diffusion model and the crisp weighted possibilistic mean normal jump-diffusion model proposed in this paper are reasonable, and can be taken as reference pricing tools for financial investors.

ZHANG, X.-L., ZHANG, K.-C. & YU, X.-J. *Optimal proportional reinsurance and investment with transaction costs: : Maximizing the terminal wealth.* 473-478. We consider a problem of optimal reinsurance and investment with multiple risky assets for an insurance company whose surplus is governed by a linear diffusion. The insurance company's risk can be reduced through reinsurance, while in addition the company invests its surplus in a financial market with one risk-free asset and n risky assets. In this paper, we consider the transaction costs when investing in the risky assets. Also, we use Conditional Value-at-Risk (CVaR) to control the whole risk. We consider the optimization problem of maximizing the expected exponential utility of terminal wealth and solve it by using the corresponding Hamilton–Jacobi–Bellman (HJB) equation. Explicit expression for the optimal value function and the corresponding optimal strategies are obtained.

ZHAO, J. *Long time behaviour of stochastic interest rate models.* 459-463. In this paper, we study the long time behaviour of two classes of stochastic interest rate models. Suppose that $x(t)$ is a one-factor interest rate model with positive jumps. For a suitable constant we prove that converges almost surely as $t \rightarrow \infty$. A similar result is also proved for a two-factor affine model.

ZHUANG, W., CHEN, Z. & HU, T. *Optimal allocation of policy limits and deductibles under distortion risk measures.* 409-414. In the literature, orderings of optimal allocations of policy limits and deductibles were established by maximizing the expected utility of wealth of the policyholder. In this paper, by applying the bivariate characterizations of stochastic ordering relations, we reconsider the same model and derive some new refined results on orderings of optimal allocations of policy limits and deductibles with respect to the family of distortion risk measures from the viewpoint of the policyholder. Both loss severities and loss frequencies are considered. Special attention is given to the optimization criteria of the family of distortion risk measures with concave distortions and with only increasing distortions. Most of the results presented in this paper can be applied to some particular distortion risk measures. The results complement and extend the main results in Cheung [Cheung, K. C., 2007. Optimal allocation of policy limits and deductibles. *Insurance: Mathematics and Economics* 41, 291-382] and Hua and Cheung [Hua, L., Cheung, K. C., 2008a. Stochastic orders of scalar products with applications. *Insurance: Mathematics and Economics* 42, 865-872].

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AHKING, F. W., GIACCOTTO, C. & SANTERRE, R. E. *The aggregate demand for private health insurance coverage in the United States.* 133-157. This article estimates the aggregate demand for private health insurance coverage in the United States using an error correction model for the period 1966-1999. Both short- and long-run price and income elasticities of demand are

estimated. The empirical findings indicate that both private insurance enrollment and the completeness of insurance are relatively inelastic with respect to changes in price and income in the short and long run. Moreover, the results suggest that an increase in the number cyclically and frictionally uninsured generates less welfare loss than an increase in the number of structurally uninsured.

BORN, P., VISCUSI, W. K. & BAKER, T. *The effects of tort reform on medical malpractice insurers' ultimate losses*. 197-219. Whereas the literature evaluating the effect of tort reforms has focused on the impact of reforms on insurers' reported incurred losses, this article examines the ultimate effects of reforms using the developed losses from a comprehensive sample of insurers writing medical malpractice insurance from 1984 to 2003. Noneconomic damages caps are particularly influential in reducing medical malpractice losses and increasing insurer profitability. The long-run effects of these reforms are greater than insurers' expected effects; for example, 5- and 7-year developed loss ratios are below the initially reported incurred loss ratios for those years following the enactment of noneconomic damages caps. Analyses of reported losses consequently understate the ultimate effects of tort reforms. The quantile regressions show that reforms have the greatest effects for the firms that are at the high end of the loss distribution.

BROWN, J. R. & FINKELSTEIN, A. *The private market for long-term care insurance in the United States : a review of the evidence*. 5-29. This article reviews the growing literature on the market for private long-term care insurance, a market notable for its small size despite the fact that long-term care expenses are potentially large and highly uncertain. After summarizing long-term care utilization and insurance coverage in the United States, the article reviews research on the supply of and the demand for private long-term care insurance. It concludes that demand-side factors impose important limits on the size of the private market and that we currently have a limited understanding of how public policies could be designed to encourage the growth of this market.

DAVIDOFF, T. *Housing, health and annuities*. 31-52. Annuities, long-term care insurance (LTCI), and reverse mortgages appear to offer important consumption smoothing benefits to the elderly, yet private markets for these products are small. A prominent idea is to combine LTCI and annuities to alleviate both supply (selection) and demand (liquidity) problems in these markets. This article shows that if consumers typically liquidate home equity only in the event of illness or very old age, then LTCI and annuities become less attractive and may become substitutes rather than complements. The reason is that the marginal utility of wealth drops when an otherwise illiquid home is sold, an event correlated with the payouts of both annuities and LTCI. Simulations confirm that demand for LTCI and annuities is highly sensitive to the liquidity and magnitude of home equity.

EGGLESTON, K. & BIT, A. *Measuring selection incentives in managed care : evidence from the Massachusetts state employee insurance program*. 159-175. Capitation gives insurers incentive to manipulate their offerings to attract the healthy and deter the sick. We calculate the incentives for such service-specific quality distortions using managed care medical and pharmacy spending data for fiscal years 2001 and 2002 from the Massachusetts State Employee Insurance Program. Services most vulnerable to stinting are cardiac care, diabetes care, and mental health and substance abuse services. Empirically, the financial temptation to distort service quality increases nonlinearly with supply-side cost sharing. Our empirical results highlight how selection incentives work at cross-purposes with efforts to reward excellent chronic disease management. Initiatives coupling pay-for-performance with risk adjustment and mixed payment hold promise for aligning incentives with quality improvement.

MC SHANE, M. K & COX, L. A. *Issuance decisions and strategic focus: the case of long-term care insurance*. 87-108. Increasing costs of long-term care are placing ever greater burdens on state and federal budgets, yet private long-term care insurance remains a relatively minor financing vehicle. Although many researchers provide rationales for the limited private market, some life-health insurers have forged ahead into this relatively new and risky line of business. We investigate what makes these insurers different and whether managers are following a diversification or strategic focus strategy. We find that strategic focus is a consistently important factor and that managers' participation and volume decisions are made independently.

MOUGEOT, M. & NAEGELEN, F. *Adverse selection, moral hazard and outlier payment policy*. 177-195. In this article, we analyze the rationale for introducing outlier payments into a prospective payment system for hospitals under adverse selection and moral hazard. The payer has only two instruments: a fixed price for patients whose treatment cost is below a threshold, and a cost-sharing rule for outlier patients. We show that a fixed-price policy is optimal when the hospital is sufficiently benevolent. When the hospital is weakly benevolent, a mixed policy solving a trade-off between rent extraction, efficiency, and dumping deterrence must be preferred. We show how the optimal combination of fixed price and partially cost-based payment depends on the degree of benevolence of the hospital, the social cost of public funds, and the distribution of patients severity.

NEALE, F. R., EASTMAN, K. L. & PETERSON DRAKE, P. *Dynamics of the market for medical malpractice insurance*. 221-247. Public attention has been directed recently at the market for medical malpractice insurance, yet disagreement persists over whether this market has changed and, if so, what has caused this change. In this study, we examine factors that affect the market for this insurance, including the growth in premiums, losses, and investment earnings, and loss variability. Our analysis suggests that there was significant deterioration in the market for medical malpractice insurance beginning in 1998 and culminating in 2001. We conclude that insurers' losses are the primary driver of the market deterioration during the period 1998 through 2003.

SMOLUK, H. J. *Long-term disability claims rates and the consumption-to-wealth ratio*. 109-131. A framework for linking long-term disability (LTD) claims rates to the macro-economy using the consumption-to-wealth ratio is developed from financial economic and option theories. Financial economic theory suggests that the consumption-to-wealth ratio reflects consumption smoothing and reveals expectations about future wealth. For individuals contemplating submitting an LTD claim, the expected payoff to exercising this insurance option is a function of their expectations about their future wealth. The lower (higher) their expectations about future wealth, the higher (lower) the expected payoff, and the higher (lower) claims rates are likely to be. Using cointegration analysis, we find that LTD claims rates and the consumption-to-wealth ratio are linked in a long-run equilibrium. When the consumption-to-wealth ratio is high (low), LTD claims rates are low (high).

WEBB, D. C. *Asymmetric information, long-term care insurance, and annuities : the case for bundled contracts*. 53-85. This article examines the markets for long-term care insurance and annuities when there is asymmetric information and there are costs of administering contracts. Individuals differ in terms of their risk aversion. Risk-averse individuals take more care of their health and are relatively high risk in the annuities market and relatively low risk in the long-term care insurance market. In the long-term care insurance market, both separating and partial-pooling equilibria are possible. However, in the stand-alone annuity market, only separating equilibria are possible. We show, consistent with the extant empirical research, that in the presence of administration costs the more risk-averse individuals may buy relatively more long-term care insurance and more annuity coverage. Under the same assumptions, we

show that equilibria exist with bundled contracts that Pareto dominate the outcomes with stand-alone contracts and are robust to competition from stand-alone contracts. The remaining empirical puzzle is to explain why bundled contracts are such a small share of the voluntary annuity market.

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ENGLUND, M., GUSTAFSSON, J., NIELSEN, J. P. & THURING, F. *Multidimensional credibility with time effects: an application to commercial business lines*. 443-453. This article considers Danish insurance business lines for which the pricing methodology has been dramatically upgraded recently. A costly affair, but nevertheless, the benefits greatly exceed the costs; without a proper pricing mechanism, you are simply not competitive. We show that experience rating improves this sophisticated pricing method as much as it originally improved pricing compared with a trivial flat rate. Hence, it is very important to take advantage of available customer experience. We verify that recent developments in multivariate credibility theory improve the prediction significantly, and we contribute to this theory with new robust estimation methods for time (in-)dependency.

KERR, D. A., MA, Y.-L. & SCHMIT, J. T. *A cross-national study of governmental social insurance as an alternative to tort liability compensation*. 367-384. Litigation rates in the United States have long been considered out of proportion with the remainder of the world, leading to a good deal of economic research trying to understand the causes. Much of that literature has focused on lawyer compensation rules and availability of general damage awards. Another possible reason for differences in national litigation rates is the relative generosity of government social programs. Using a sample of 24 countries over a 12-year period, we test the relationship between the size of government social program payments and liability costs as measured by liability insurance premiums, and find a strong negative relationship, controlling for income, accident rates, and a variety of other factors.

KIM, H., KIM, D., IM, S. & HARDIN, J. W. *Evidence of asymmetric information in the automobile insurance market: Dichotomous versus multinomial measurement of insurance coverage*. 343-366. In the empirical analysis of information asymmetry in automobile insurance markets, prior research used a dichotomous measurement approach that induces excessive bundling in coverage measurements and sample selection biases. To improve on the conditional correlation method for testing information asymmetry, we propose a multinomial measurement approach that constructs coverage categories at ordered multinomial levels. With this approach, we find robust evidence of information asymmetry in both coverage area and coverage amount choices, which we could not find with the dichotomous measurement approach. It thus demonstrates the sensitivity of the empirical findings to the method used to measure insurance coverage.

MACDONALD, B.-J. & CAIRNS, A. J. G. *Getting feedback on defined contribution pension plans*. 385-417. With the growth of private and public defined contribution (DC) pension plans around the world, market rates of return should increasingly play a large role in the retirement patterns of individuals. The reverse could, however, also be true — i.e. a country's population demographics could influence the financial markets. In this article, we model the potential impact of aggregate retirement patterns on macroeconomic variables with the goal of further understanding the implications of a traditional DC pension becoming the predominant source of retirement income for an entire society. We find that the economic-system feedback dampens fluctuations in the size of the working population.

SEOG, S. H. *Insurance markets with differential information*. 279-294. This article attempts to understand the outcomes when each party of an insurance contract simultaneously has superior information. I assume that policyholders have superior information about specific risks while insurers have superior information about general risks. I find that low-general-risk policyholders purchase insurance, while high-general-risk policyholders are self-insured. Among the low-general-risk policyholders, high-specific-risk policyholders purchase full insurance, while low-specific-risk policyholders purchase partial insurance. When insurers can strategically publicize their information, efficiency is improved because high-general-risk policyholders purchase actuarially fair insurance. The market segmentation is also found based on the general-risk type and the publicizing of information.

SNOW, A. *On the possibility of profitable self-selection contracts in competitive insurance markets*. 249-259. Several studies extend the Rothschild-Stiglitz model of competitive insurance contracting with adverse selection by incorporating additional dimensions of private information and conclude that some insurers may earn positive profit in a separating, self-selection equilibrium, provided each insurer is restricted to making a single contract offer. The main result of this article is that these profitable configurations are not sustainable when individual insurers can offer multiple contracts. It is also shown that the ability to offer multiple contracts overturns equilibria that have applicants from different risk classes pooled as well as those where profits are dissipated by a fixed entry cost.

Sonnenholzner, M. & Wambach, A. *On the role of patience in an insurance market with asymmetric information*. 323-341. We analyze a two-period competitive insurance market that is characterized by the simultaneous presence of moral hazard and adverse selection with regard to consumer time preferences. It is shown that there exists an equilibrium in which patient consumers use high effort and buy an insurance contract with high coverage, whereas impatient consumers use low effort and buy a contract with low coverage or even remain uninsured. This finding may help to explain why the opposite of adverse selection with regard to risk types can sometimes be observed empirically.

SPREEUW, J. & KARLSSON, M. *Time deductibles as screening devices : competitive markets*. 261-278. Seminal papers on asymmetric information in competitive insurance markets, analyzing the monetary deductible as a screening device, show that any existing equilibrium is of a separating type. High risks buy complete insurance, whereas low risks buy partial insurance — and this result holds for the Nash behavior as well as for the Wilson foresight. In this article, we analyze the strength of screening based on limitations to the period of coverage of the contract. We show that in this case (1) the Nash equilibrium may entail low risks not purchasing any insurance at all, and (2) under the Wilson foresight, a pooling equilibrium may exist.

TSAI, C. *The term structure of reserve durations and the duration of aggregate reserves*. 419-441. Estimating the duration gap of a life insurer demands the knowledge on the durations of liabilities and assets. The literature analyzed the durations of assets extensively but rendered limited analyses on the durations of insurance liabilities. This article calculated the reserve durations for individual policies and estimated the duration of the aggregate reserves. The results showed that the duration of the policy reserve might be negative and/or have a large figure. They further revealed an interesting pattern of the reserve duration with respect to the policy's time to maturity. A term structure with abnormal durations, however, does not result in an abnormal duration of the aggregate reserves.

ZHANG, T., COX, L. A. & VAN NESS, R. A. *Adverse selection and the opaqueness of insurers*. 295-321. While adverse selection problems between insureds and insurers are well known to insurance researchers, few explore adverse selection in the insurance industry from a capital

markets perspective. This study examines adverse selection in the quoted prices of insurers' common stocks with a particular focus on the opacity of both asset portfolios and underwriting liabilities. We find that more opaque underwriting lines result in greater adverse selection costs for property-casualty (P-C) insurers. A similar effect is not apparent for life-health (L-H) insurers and we find no effect of asset opacity on adverse selection for either L-H or P-C insurers.

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BARRIEU, P. & LOUBERGÉ, H. *Hybrid cat bonds*. 547-578. Natural catastrophes attract regularly the media attention and have become a source of public concern. From a financial viewpoint, they represent idiosyncratic risks, diversifiable at the world level. But for various reasons, reinsurance markets are unable to cope with this risk completely. Insurance-linked securities, such as catastrophe (cat) bonds, have been issued to complete the international risk transfer process, but their development is disappointing so far. This article argues that downside risk aversion and ambiguity aversion explain their limited success. Hybrid cat bonds, combining the transfer of cat risk with protection against a stock market crash, are proposed to complete the market. The article shows that replacing simple cat bonds with hybrid cat bonds would lead to an increase in market volume.

BERNARD, C. & TIAN, W. *Optimal reinsurance arrangements under tail risk measures*. 709-725. Regulatory authorities demand insurance companies control their risk exposure by imposing stringent risk management policies. This article investigates the optimal risk management strategy of an insurance company subject to regulatory constraints. We provide optimal reinsurance contracts under different tail risk measures and analyze the impact of regulators' requirements on risk sharing in the reinsurance market. Our results underpin adverse incentives for the insurer when compulsory Value-at-Risk risk management requirements are imposed. But economic effects may vary when regulatory constraints involve other risk measures. Finally, we compare the obtained optimal designs to existing reinsurance contracts and alternative risk transfer mechanisms on the capital market.

CHEN, H. & COX, S. H. *Modeling mortality with jumps: applications to mortality securitization*. 727-751. In this article, we incorporate a jump process into the original Lee-Carter model, and use it to forecast mortality rates and analyze mortality securitization. We explore alternative models with transitory versus permanent jump effects and find that modeling mortality via transitory jump effects may be more appropriate in mortality securitization. We use the Swiss Re mortality bond in 2003 as an example to show how to apply our model together with the distortion measure approach to value mortality-linked securities. Pricing the Swiss Re mortality bond is challenging because the mortality index is correlated across countries and over time. Cox, Lin, and Wang (2006) employ the normalized multivariate exponential tilting to take into account correlations across countries, but the problem of correlation over time remains unsolved. We show in this article how to account for the correlations of the mortality index over time by simulating the mortality index and changing the measure on paths.

CUMMINS, J. D. & WEISS, M. A. *Convergence of insurance and financial markets: hybrid and securitized risk-transfer solutions*. 493-545. One of the most significant economic developments of the past decade has been the convergence of the financial services industry, particularly the capital markets and (re)insurance sectors. Convergence has been driven by the increase in the frequency and severity of catastrophic risk, market inefficiencies created by (re)insurance underwriting cycles, advances in computing and communications technologies, the emergence

of enterprise risk management, and other factors. These developments have led to the development of hybrid insurance/financial instruments that blend elements of financial contracts with traditional reinsurance as well as new financial instruments patterned on asset-backed securities, futures, and options that provide direct access to capital markets. This article provides a survey and overview of the hybrid and pure financial markets instruments and provides new information on the pricing and returns on contracts such as industry loss warranties and Cat bonds.

CUMMINS, J. D. & DIONNE, G. *Introduction to the SCOR-JRI special issue on new forms of risk financing and risk engineering.* 459-462.

CUMMINS, J. D. & TRAINAR, P. *Securitization, insurance and reinsurance.* 463-492. This article considers strengths and weaknesses of reinsurance and securitization in managing insurable risks. Traditional reinsurance operates efficiently in managing relatively small, uncorrelated risks and in facilitating efficient information sharing between cedants and reinsurers. However, when the magnitude of potential losses and the correlation of risks increase, the efficiency of the reinsurance model breaks down, and the cost of capital may become uneconomical. At this juncture, securitization has a role to play by passing the risks along to broader capital markets. Securitization also serves as a complement for reinsurance in other ways such as facilitating regulatory arbitrage and collateralizing low-frequency risks.

ELING, M. & TOPLEK, D. *Modeling and management of nonlinear dependencies—copulas in dynamic financial analysis.* 651-681. We study the influence of nonlinear dependencies on a non-life insurer's risk and return profile. To achieve this, we integrate several copula models in a dynamic financial analysis framework and conduct numerical tests. We also test risk management strategies in response to adverse outcomes. Nonlinear dependencies have a crucial influence on the insurer's risk profile that can hardly be affected by the analyzed management strategies. We find large differences in risk assessment for the ruin probability and for the expected policyholder deficit. This has important implications for insurers, regulators, and rating agencies that use these measures as a foundation for internal risk models, capital standards, and ratings.

EMBRECHTS, P. *Copulas: a personal view.* 639-650. Copula modeling has taken the world of finance and insurance, and well beyond, by storm. Why is this? In this article, I review the early start of this development, discuss some important current research, mainly from an applications point of view, and comment on potential future developments. An alternative title of the article would be "Demystifying the copula craze". The article also contains what I would like to call the copula must-reads.

FINKEN, S. & LAUX, C. *Catastrophe bonds and reinsurance: the competitive effect of information-insensitive triggers.* 579-605. We identify a new benefit of index or parametric triggers. Asymmetric information between reinsurers on an insurer's risk affects competition in the reinsurance market: reinsurers are subject to adverse selection, since only high-risk insurers may find it optimal to change reinsurers. The result is high reinsurance premiums and cross-subsidization of high-risk insurers by low-risk insurers. A contract with a parametric or index trigger (such as a catastrophe bond) is insensitive to information asymmetry and therefore alters the equilibrium in the reinsurance market. Provided that basis risk is not too high, the introduction of contracts with parametric or index triggers provides low-risk insurers with an alternative to reinsurance contracts, and therefore leads to less cross-subsidization in the reinsurance market.

GOURIEROUX, C. & LIU, W. *Control and out-of-sample validation of dependent risks.* 683-707. This article introduces a framework to determine and allocate capital reserves to multiple dependent business lines, with or without overall reserve level constraints. The proposed

methodology emphasizes the role of the loss function in the validation criterion and its conditional interpretation. Univariate and multivariate examples are discussed in detail.

JAWADI, F., BRUNEAU, C. & SGHAIER, N. *Nonlinear cointegration relationships between non-life insurance premiums and financial markets*. 753-783. The aim of this article is to study the adjustment dynamics of the non-life insurance premium (NLIP) and test its dependence to the financial markets in five countries (Canada, France, Japan, the United Kingdom, and the United States). First, we justify the linkage between the insurance and the financial markets by the underwriting cycle theory and financial models of insurance pricing. Second, we examine the relationship between the NLIP, the interest rate, and the stock price using the recent developments of nonlinear econometrics. We use threshold cointegration models: the switching transition error correction models (STECM). We show that STECM perform better than a linear error correction model (LECM) to reproduce the NLIP dynamics. Our empirical results show that the adjustment of the NLIP in France, Japan, and the United States is rather discontinuous, asymmetrical, and nonlinear. Moreover, we suggest a strong evidence of significant linkages between insurance and financial markets, show two regimes for the NLIP, and find that the NLIP adjustment toward equilibrium is time varying with a convergence speed that varies according to the insurance disequilibrium size.

KLEIN, R. W. & WANG, S. *Catastrophe risk financing in the United States and the European Union: a comparative analysis of alternative regulatory approaches*. 607-637. The regulation of insurance companies in the United States and the European Union (EU) continues to evolve in response to market forces and the changing nature of risk but with somewhat different philosophies and at different rates. One important area where both economic realities and markets are changing is catastrophe risk and its financing. This article examines and compares regulatory and other government policies in the United States and the EU generally and their approaches to the financing of catastrophe risk specifically. It is important to understand the fundamental differences between the two systems to gain insights into their disparate treatment of catastrophe risk financing. Although policies could be improved in both jurisdictions, we argue that the much greater reform is needed in the United States relative to the EU regulatory policies that are being developed. We offer recommendations on how U.S. policies could be significantly improved as well as comment on issues facing the EU. We conclude with some observations on the needs for further progress in the U.S. and EU regulatory systems.

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BAYRAKTAR, E., MOORE, K. S. & YOUNG, V. R. *Minimizing the probability of lifetime ruin under random consumption*. 384-400. We determine the optimal investment strategy in a financial market for an individual whose random consumption is correlated with the price of a risky asset. Bayraktar and Young consider this problem and show that the minimum probability of lifetime ruin is the unique convex, smooth solution of its corresponding Hamilton–Jacobi–Bellman equation. In this paper we focus on determining the probability of lifetime ruin and the corresponding optimal investment strategy. We obtain approximations for the probability of lifetime ruin or small values of certain parameters and demonstrate numerically that they are reasonable ones. We also obtain numerical results in cases for which those parameters are not small.

BAYRAKTAR, E. & YOUNG, V. R. *Minimizing the probability of ruin when consumption is ratcheted.* 428-442. We assume that an agent's rate of consumption is ratcheted; that is, it forms a nondecreasing process. We assume that the agent invests in a financial market with one riskless and one risky asset, with the latter's price following geometric Brownian motion as in the Black-Scholes model. Given the rate of consumption, we act as financial advisers and find the optimal investment strategy for the agent who wishes to minimize his probability of ruin. To solve this minimization problem, we use techniques from stochastic optimal control.

CHISHOLM, D. & BROWN, R. *Negative effects of the Canadian GIS clawback and possible mitigating alternatives.* 272-383. In Canada there are three main sources of government-provided retirement income: the Canada/Quebec Pension Plans (C/QPP), which have benefits and contributions based on earnings up to the Yearly Maximum Pensionable Earnings; Old Age Security (OAS), which is a fixed amount for most but does include a 'clawback' of benefits for high-income individuals; and the Guaranteed Income Supplement (GIS), which is designed to supplement those persons with extremely low income. The annual GIS benefit is reduced, or clawed back, by 50 cents for every dollar of annual income the person has in retirement, including C/QPP and income from Registered Retirement Savings Plans (RRSPs) and other savings. OAS benefits are not included in determining the GIS clawback. The result of this is that low-income individuals who attempt to enhance their retirement replacement ratio actually see a decrease in government-provided support the more they save for retirement. Savings in an RRSP can effectively be taxed at more than 100% through corresponding reductions in the GIS, social housing, home care, GAINS (Ontario's Guaranteed Annual Income Supplement), and other benefits that are based on one's personal retirement income. This paper explores alternatives to the 50% GIS clawback including a basic GIS exemption, a GIS clawback rate lower than 50%, and a combination of the two. The goal is to improve the fairness of the GIS and reduce the disincentive to save for retirement, without increasing the overall cost of the program significantly.

GOULET, V. & POULIOT, L.-P. *Simulation of compound hierarchical models in R.* 401-412. Hierarchical probability models are widely used in insurance applications for data classified in a tree-like structure and in Bayesian inference. We propose an R function to simulate data from compound models in which both the frequency component and the severity component can have a hierarchical structure. The model description method is based solely on R expressions, and it allows for models with any number of levels and nodes per level, as well as with very general conditional probability structures. The function is part of the R package *actuar*.

LI, S. *The time of recovery and the maximum severity of ruin in a Sparre Andersen model.* 413-427. Phase-type distributions are one of the most general classes of distributions permitting a Markovian interpretation. Sparre Andersen risk models with phase-type claim interarrival times or phase-type claims can be analysed using Markovian techniques, and results can be expressed in compact matrix forms. Computations involved are readily programmable in practice. This paper studies some quantities associated with the first passage time and the time of ruin in a Sparre Andersen risk model with phase-type interclaim times. In a previous discussion the present author obtained a matrix expression for the Laplace transform of the first time that the surplus process reaches a given target from the initial surplus. Using this result, we analyse (1) the Laplace transform of the recovery time after ruin, (2) the probability that the surplus attains a certain level before ruin and (3) the distribution of the maximum severity of ruin. We also give a matrix expression for the expected discounted dividend payments prior to ruin for the Sparre Andersen model in the presence of a constant dividend barrier.

WANG, L., VALDEZ, E. A. & PIGGOTT, J. *Securitization of longevity risk in reverse mortgages*. 345-371. The reverse mortgage market has been expanding rapidly in developed economies in recent years. The onset of demographic transition places a rapidly rising number of households in an age window in which reverse mortgages have potential appeal. Increasing prices for residential real estate over the last decade have further stimulated interest. Reverse mortgages involve various risks from the provider's perspective that may hinder the further development of these financial products. This paper addresses one method of transferring and financing the risks associated with these products through the form of secularization. Securitization is becoming a popular and attractive alternative form of risk transfer of insurance liabilities. Here we demonstrate how to construct a secularization structure for reverse mortgages similar to the one applied in traditional insurance products. Specifically, we investigate the merits of developing survivor bonds and survivor swaps for reverse mortgage products. In the case of survivor bonds, for example, we are able to compute premiums, both analytically and numerically through simulations, and to examine how the longevity risk may be transferred to the financial investors. Our numerical calculations provide an indication of the economic benefits derived from developing survivor bonds to securitize the 'longevity risk component' of reverse mortgage products. Moreover, some sensitivity analysis of these economic benefits indicates that these survivor bonds provide for a promising tool for investment diversification.

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BAYRAKTAR, E. & YOUNG, V. R. *Minimizing the probability of lifetime ruin with deferred life annuities*. 14. We find the minimum probability of lifetime ruin of an investor who can invest in a market with a risky and a riskless asset and who can purchase a deferred life annuity. Although we let the admissible set of strategies of annuity purchasing process be the set of increasing adapted processes, we find that the individual will not buy a deferred life annuity unless she can cover all her consumption via the annuity and have enough wealth left over to sustain her until the end of the deferral period.

BOUDREAU, M. & PANNETON, C.-M. *Multivariate models of equity returns for investment guarantees valuation*. 36-53. In this paper we investigate the valuation of investment guarantees in a multivariate (discrete-time) framework. We present how to build multivariate models in general, and we survey the most important multivariate GARCH models. A direct multivariate application of regime-switching models is also discussed, as is the estimation of these models using maximum likelihood and their comparison in a multivariate setting. The computation of the CTE provision is further presented. We have estimated the models with a multivariate dataset (Canada, United States, United Kingdom, and Japan), and we compared the quality of their fit using multiple criteria and tests. We observe that multivariate GARCH models provide a better overall fit than regime-switching models. However, regime-switching models appropriately represent the fat tails of the returns distribution, which is where most GARCH models fail. This leads to significant differences in the value of the CTE provisions, and, in general, provisions computed with regime-switching models are higher. Thus, the results from this multivariate analysis are in line with what was obtained in the literature of univariate models.

CAIRNS, A. J. G., BLAKE, D., DOWD, K., COUGHLAN, G. D., EPSTEIN, D., ONG, A. & BALEVICH, I. *A quantitative comparison of stochastic mortality models using data from England and Wales and the United States*. 1-35. We compare quantitatively eight stochastic models explaining improvements in mortality rates in England and Wales and in the United States. On the basis of the Bayes Information Criterion (BIC), we find that, for higher ages, an

extension of the Cairns–Blake–Dowd (CBD) model that incorporates a cohort effect fits the England and Wales males data best, while for U.S. males data, the Renshaw and Haberman (RH) extension to the Lee and Carter model that also allows for a cohort effect provides the best fit. However, we identify problems with the robustness of parameter estimates under the RH model, calling into question its suitability for forecasting. A different extension to the CBD model that allows not only for a cohort effect, but also for a quadratic age effect, while ranking below the other models in terms of the BIC, exhibits parameter stability across different time periods for both datasets. This model also shows, for both datasets, that there have been approximately linear improvements over time in mortality rates at all ages, but that the improvements have been greater at lower ages than at higher ages, and that there are significant cohort effects.

CHEN, H. & COX, S. H. *An option-based operational risk management model for pandemics.* 54-76. In this paper we employ the theory of real option pricing to address problems in the area of operational risk management. We develop a two-stage model to help firms determine the optimal suspension-reactivation triggers in the events of pandemics. In the first stage, we propose a regime-dependent epidemic model to simulate the spread of the virus, depending on whether the firm is active or inactive. In the second stage, we view the reactivation decision as a call option and the suspension decision as a put option, and use dynamic programming methods to obtain the optimal switching thresholds. Our method can be regarded as a quantitative implementation of the CDC's instructions for pandemic preparation. We find that when they take the uncertainty of disease transmission into consideration, firms are more conservative about the decisions of suspension and reactivation. We also find that when firms incur switching costs, the suspension threshold increases with costs, whereas the reactivation threshold decreases with costs. By adopting disease control policies, firms can increase their values in both regimes.

EMMS, P. & HABERMAN, S. *Optimal management of an insurer's exposure in a competitive general insurance market.* 77-105. The qualitative behavior of the optimal premium strategy is determined for an insurer in a finite and an infinite market using a deterministic general insurance model. The optimization problem leads to a system of forward-backward differential equations obtained from Pontryagin's Maximum Principle. The focus of the modelling is on how this optimization problem can be simplified by the choice of demand function and the insurer's objective. Phase diagrams are used to characterize the optimal control. When the demand is linear in the relative premium, the structure of the phase diagram can be determined analytically. Two types of premium strategy are identified for an insurer in an infinite market, and which is optimal depends on the existence of equilibrium points in the phase diagram. In a finite market there are four more types of premium strategy, and optimality depends on the initial exposure of the insurer and the position of a saddle point in the phase diagram. The effect of a nonlinear demand function is examined by perturbing the linear price function. An analytical optimal premium strategy is also found using inverse methods when the price function is nonlinear.

LUDKOVSKI, M. & BAYRAKTAR, E. *Relative hedging of systematic mortality risk.* 106-140. We study indifference valuation mechanisms for mortality contingent claims under stochastic mortality age structures. Our focus is on capturing the internal cross-hedge between components of an insurer's portfolio, especially between life annuities and life insurance. We carry out an exhaustive analysis of the dynamic exponential premium principle, which is the representative nonlinear valuation rule in our framework. Using this valuation rule we derive formulas for optimal quantity of contracts to sell. Our results are further enhanced by asymptotic expansions that show the relative effects of model parameters. We also compare the exponential premium principle to other valuation rules. Furthermore, we provide numerical examples to illustrate our approach.

REN, J. Discussion of 'The time recovery and the maximum severity of ruin in a Sparre Andersen Model', Li, Shuanming, October 2008. 155-156.

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ANDREWS, D. & BROWN, R. L. *Is defined contribution a panacea for defined benefit social security funding problems? Lessons from two countries.* 186-201. Many countries are changing their social security retirement program from a defined benefit (DB) to a defined contribution (DC) basis. Other countries, such as the United States, are discussing the introduction of a DC component. The replacement of a DB social security retirement system by a DC system raises many important social and economic issues. Thoughtful consideration must be given to the choice of a criteria for prioritizing objectives and outcomes, as well as in weighing the advantages and disadvantages between different cohorts. For example, if any DB obligations are not fully funded at transition, a double burden will rest with transition generation(s). Moreover, economists tend to assess the value of the system based on measures of economic efficiency and the lack of impediments to a freely operating labour market. But such an assessment may not give adequate recognition to factors such as individual wealth/poverty, an individual's ability to make optimal investment decisions, and transaction costs associated with operating individual accounts. Indeed, some countries have suggested that notional defined contribution (NDC) accounts may be the best way to address such issues.

Focusing on the adoption of a funded DC social security retirement program in Chile and the adoption of a pay-as-you-go NDC social security retirement program by Sweden, this research identifies factors of financial markets, economics, and demographics necessary to enable a move to DC accounts. In addition, it identifies the characteristics of the financial markets necessary to support payments (wealth transfers) to retirees from a DC social security retirement program.

The paper considers the question of social security funding and plan type (DB vs DC) and attempts to assess the suitability of certain reform options for the United States. It approaches the issue by identifying the features of each type and the strengths and weaknesses associated with those features. A significant part of this analysis is the illustrative description of two real-world plans, Chilean and Swedish. It then uses the theoretical considerations and the experience of those plans to draw conclusions about reform proposals in the United States, particularly the President's Commission to Strengthen Social Security Model 2.

AVANZI, B. *Strategies for dividend distribution: a review.* 217-251. In today's world of financial uncertainty, one major public concern is to assess (and possibly improve) the stability of companies that take on risks. Actuaries have been aware of that issue for a very long time and have a great experience in modeling the activity of a risk business. During the first part of the twentieth century, they focused on the probability of ruin to assess the stability of their company. In his seminal paper of 1957 Bruni de Finetti criticized this approach and laid the foundations of what would become an increasingly popular topic: the study of dividend strategies. The contributions made by actuaries in that field constitute a substantial body of knowledge, whose interest is relevant not only to insurance but also to a much broader range of areas of practice. In this paper we aim at a taxonomical synthesis of the 50 years of actuarial research that followed de Finetti's original paper.

- LANDRIAULT, D. & WILLMOT, G. E. *On the joint distributions of the time to ruin, the surplus prior to ruin, and the deficit at ruin in the classical risk model.* 252-279. The seminal paper by Gerber and Shiu (1998) unified and extended the study of the event of ruin and related quantities, including the time at which the event of ruin occurs, the deficit at the time of ruin, and the surplus immediately prior to ruin. The first two of these quantities are fundamentally important for risk management techniques that utilise the ideas of Value-at-Risk and Tail Value-at-Risk. As is well known, calculation of these and related quantities requires knowledge of the associated probability distributions. In this paper we derive an explicit expression for the joint (defective) distribution of the time to ruin, the surplus immediately prior to ruin, and the deficit at ruin in the classical compound Poisson risk model. As a by-product, we obtain expressions for the three bivariate distributions generated by the time to ruin, the surplus prior to ruin, and the deficit at ruin. Finally, we consider mixing Erlang claim sizes and show how the joint (defective) distribution of the time to ruin, the surplus prior to ruin, and the deficit at ruin can be calculated.
- MELO, E. F. L. & MENDES, B. V. D. M. *Pricing participating inflation retirement funds through option modeling and copulas.* 170-185. Pension plans and life insurance offering minimum performance guarantees are very common worldwide. In the Brazilian market, the customers of a common type of defined contribution plan have the right to receive, over their savings, the positive difference between the return of a specified investment fund, usually a fixed income fund, and the minimum guaranteed rate, commonly defined as the composition of a fixed interest rate and a floating inflation rate. This instrument can be characterized as an option to exchange one asset, the minimum guaranteed rate, for another, the return of the specified investment fund. In this paper we provide a closed formula to evaluate this liability that depends on two stochastic rates assuming bivariate normality. We also explore the use of copulas for the modeling of the dependence structure and price the options using Monte Carlo simulation to compare the effects of the copula specification in their values. An application with real data is provided. The model makes use of a one-factor Vasicek framework for the term structures of interest rate and inflation rate.
- NIELSON, N. L. *Examining the effects of guarantee funds on pension plans.* 157-169. Bankruptcy risk falls to pension plan participants if a plan sponsor fails when a defined benefit (DB) pension plan is underfunded. This article examines the incidence of that risk and how it changes when public policy provides a guarantee fund. Although government-based guarantee funds are in a unique position to provide pension protection, primarily because of the extent to which the risk of sponsor default is systematic in nature, a looming question is the extent to which such guarantees are exposed to moral hazard. This article focuses on that question using data from four Canadian provinces, including one (Ontario) that operates a guarantee fund for pensions. The findings show that plan assets per DB-plan participant increase with the earnings of workers and decrease with higher unemployment, and that level of assets also is moderated by the influence of taxes, with higher plan assets observed when and where tax rates are higher. Plans in Ontario had on average \$20,035 less in asset value per participant, and Ontario plans covered by the guarantee fund had an average of \$16,497 less per participant than other Canadian DB plans not backed by a guarantee fund. A separate model finds the presence of a guarantee fund to be one of a very small number of variables significant in explaining variability in the plans' funded ratios. These empirical results are consistent with the existence of moral hazard.
- VERDONCK, T., VAN WOUWE, M. & DHAENE, J. *A robustification of the chain-ladder method.* 280-298. In a non-life insurance business an insurer often needs to build up a reserve to be able to meet his or her future obligations arising from incurred but not reported completely claims. To forecast these claims reserves, a simple but generally accepted algorithm is the classical chain-ladder method. Recent research essentially focused on the underlying model for

the claims reserves to come to appropriate bounds for the estimate of future claims reserves. Our research concentrates on scenarios with outlying data. On closer examination it is demonstrated that the forecasts for future claims reserves are very dependent on outlying observations. The paper focuses on two approaches to robustify the chain-ladder method: the first method detects and adjusts the outlying values, whereas the second method is based on a robust generalized linear model technique. In this way insurers will be able to find a reserve that is similar to the reserve they would have found if the data contained no outliers. Because the robust method flags the outliers, it is possible to examine these observation for further examination. For obtaining the corresponding standard errors the bootstrapping technique is applied. The robust chain-ladder method is applied to several run-off triangles with and without outliers, showing its excellent performance.

WONG, H. Y. & LAM, K. W. *Valuation of discrete dynamic fund protection under Levy processes*. 202-216. This paper investigates the valuation of discrete dynamic fund protection (DFP) under Levy processes. Specifically, the analytical solution of the discrete DFP under Levy processes is obtained in terms of Fourier transforms. The derivation uses Spitzer's formula and leads to a recursion on computing the characteristic function of the maximum protection-to-fund ratio using the Fourier inversion. DFP can then be valued efficiently and accurately via the fast Fourier transform. The pricing behaviour of the discrete DFP is numerically examined using several Levy processes, such as geometric Brownian motion, jump-diffusion models, and variance gamma process. Numerical experiments confirm that the proposed approach produces highly accurate discrete DFP values within 1 second.

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BRAZAUSKAS, V. *Robust and efficient fitting of loss models: diagnostic tools and insights*. 356-369.

We consider robust and efficient fitting of claim severity models whose parameters are estimated using the method of trimmed moments, which was recently introduced by Brazauskas, Jones, and Zitikis. In this article, we take the "next" step by going beyond the theory and simulations. We address important issues that arise in practical applications of the method. Specifically, we introduce two graphical diagnostic tools that can be used to choose the trimming proportions and hence help one decide on the appropriate trade-off between robustness and efficiency. What is equally important, such tools are useful in model selection, for assessing the overall goodness of model fit, and for identification of outliers. Some insights about the choice between a "good" fit and an "even better" fit and its impact on risk evaluations are provided. Data analysis and illustrations are performed using real data that represent the total damage done by 827 fires in Norway in the year 1988.

BROCKETT, P. L., GOLDEN, L. L., WEN, M.-M. & YANG, C. C. *Pricing weather derivatives using the indifference pricing approach*. 303-315. This paper adopts an incomplete market pricing model — the indifference pricing approach — to analyze valuation of weather derivatives and the viability of the weather derivatives market in a hedging context. It incorporates price risk, weather / quantity risk, and other risks in the financial market. In a mean-variance framework, the relationship between the actuarial price and the indifference price of weather derivatives is analyzed, and conditions are obtained concerning when the actuarial price does not provide an appropriate valuation for weather derivatives. Conditions for the viability of the weather derivatives market are examined. This paper also analyzes the effects of partial hedging, natural hedges, basis risk, quantity risk, and price risk on investors' indifference prices by examining the distributional impacts of the stochastic variables involved.

DENUIT, M. & FROSTIG, E. *Life insurance mathematics with random life tables*. 339-355. When the insurer sells life annuities, projected life tables incorporating a forecast of future longevity must be used for pricing and reserving. To fix the ideas, the framework of Lee and Carter is adopted in this paper. This paper aims to investigate some aspects of actuarial mathematics in the context of random life tables. First, the type of dependence existing between the insured life lengths is carefully examined. The way positive dependence influences the need for economic capital is assessed compared to mutual independence, as well as the effect of the timing of deaths through Bayesian credibility mechanisms. Then the distribution of the present value of payments under a closed group of life annuity policies is studied. Failing to account for the positive dependence between insured lifetimes is a dangerous strategy, even if the randomness in the future survival probabilities is incorporated in the actuarial computations. Numerical illustrations are performed on the basis of Belgian mortality statistics. The impact of the distribution of the present value of the additional variability that results from the Lee-Carter model is compared with the traditional method of mortality projection. Also, the impact of ignoring the dependence that arises from the model is quantified.

IYENGAR, G. & MA, A. K. C. *Cash flow matching: A risk management approach*. 370-384. We propose a scenario-based optimization framework for solving the cash flow matching problem where the time horizon of the liabilities is longer than the maturities of available bonds and the interest rates are uncertain. Standard interest rate models can be used for scenario generation within this framework. The optimal portfolio is found by minimizing the cost at a specific level of shortfall risk measured by the conditional tail expectation (CTE), also known as conditional value-at-risk (CVaR) or Tail-VaR. The resulting optimization problem is still a linear program (LP) as in the classical cash flow matching approach. This framework can be employed in situations when the classical cash flow matching technique is not applicable.

LIN, X. S., TAN, K. S. & YANG, H. *Pricing annuity guarantees under a regime-switching model*. 316-338. We consider the pricing problem of equity-linked annuities and variable annuities under a regime-switching model when the dynamic of the market value of a reference asset is driven by a generalized geometric Brownian motion model with regime switching. In particular, we assume that regime switching over time according to a continuous-time Markov chain with a finite number state space representing economy states. We use the Esscher transform to determine an equivalent martingale measure for fair valuation in the incomplete market setting. The paper is complemented with some numerical examples to highlight the implications of our model on pricing these guarantees.

TRUFIN, J., ALBRECHER, H. & DENUIT, M. *Impact of underwriting cycles on the solvency of an insurance company*. 385-403. This paper studies the solvency of an insurance firm in the presence of underwriting cycles. A small or medium-size insurance company with a price-taker position in the market is considered. Its premium income is assumed to obey an autoregressive process with cycles. Specifically, the premium income for a specific calendar year is influenced by the market experience of the last couple of years. Under this classical AR(2) dynamics governing the premium income, an explicit expression for the ultimate ruin probability is derived, using a martingale approach, in the light-tailed claims case. Furthermore, the logarithmic asymptotic behaviour of the ultimate ruin probability as well as the typical path to ruin are investigated. Then a comparison is made with the classical case where the same company operates on a market without such cycles. Asymptotically, the presence of market cycles is shown to increase the risk for the company. Numerical illustrations are performed on Canadian motor insurance market data and support the theoretical analysis.

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DELONG, L. *Indifference pricing of a life insurance portfolio with systematic mortality risk in a market with an asset driven by a Levy process.* 1-26. In this paper, we investigate the problem of pricing and hedging of life insurance liabilities. We consider a financial market consisting of a risk-free asset with a constant rate of return, and a risky asset whose price is driven by a Levy process. We take into account a systematic mortality risk and model mortality intensity as a diffusion process. The principle of equivalent utility is chosen as the valuation rule. In order to solve our optimization problems, we apply techniques from the stochastic control theory. An exponential utility is considered in detail. We arrive at three pricing equations and investigate some properties of the premiums. An estimate of the finite-time ruin probability is derived. Indifference pricing with respect to a quadratic loss function is also briefly discussed.

FLORES, C. *Management of catastrophic risks considering the existence of early warning systems.* 38-62. It is crucially important to incorporate the notion of early warning systems in insurance mathematics. We develop the theory of an arrival process taking into account an early warning system, and we use it to create appropriate actuarial models. Then, we formulate a stochastic optimization problem to find an investment strategy for the management of a fund from the perspective of a risk-averse government. The solution is given using the Follmer-Schweizer strategy.

RAMSAY, C. M. *The distribution of compound sums of Preto distributed losses.* 27-37. An expression is derived for the cumulative distribution function which is the aggregate losses in a period, where N is the random number of losses and the X_k 's are independent and identically distributed Pareto random variables. Specific expressions are derived for the two most commonly used compound models in actuarial risk theory: the compound Poisson and the compound negative binomial.

WÜTHRICH, M. V., MERZ, M. & LYSENKO, N. *Uncertainty of the claims development result in the chain ladder method.* 63-84. Using the distribution-free chain ladder method, we estimate the total ultimate claim amounts at time t , and after updating the information, at time $t+1$. The observable claims development result at time $t+1$ for accounting year $(t, t+1]$ is then defined to be the difference between these two successive best estimate predictions for the ultimate claim. We analyze the uncertainty of this observable claims development result.

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ALBERS, W., KALLENBERG, W. C. M. & LUKOCIUS, V. *A flexible model for actuarial risks under dependence.* 152-167. Methods for computing risk measures, such as stop-loss premiums, tacitly assume independence of the underlying individual risks. This can lead to huge errors

even when only small dependencies occur. In the present paper, a general model is developed which covers what happens in practice in a realistic way. Moreover, it is also flexible, in the sense that it allows application in practice. Accurate and transparent approximations are presented, and the results obtained are illustrated through explicit examples.

BARBARIN, J., DE LAUNOIS, T. & DEVOLDER, P. *Risk minimization with inflation and interest rate risk: applications to non-life insurance*. 119-151. This paper aims at studying the asset allocation problem of a non-life insurance company when inflation risk and interest rate risk are taken into account. To this purpose, we apply the risk-minimization theory developed by Fllmer & Sondermann (1986) and extended by Miller (2001). We derive the general form of the risk-minimizing strategies when the cumulative payments of the insurer are described, as suggested by Arjas (1989), by a process adapted to the natural filtration of a marked point process and when the inflation and the term structure of interest rates are simultaneously described by the HJM model of Jarrow & Yildirim (2003). We then apply our general results in two collective models and two individual models of non-life insurance payments.

LANDSMAN, Z. *Elliptical families and copulas: tilting and premium; capital allocation*. 85-103. Elliptical copula measures with symmetrical marginals are proposed as a natural generalization of the elliptical family, which preserves the symmetrical character of marginals, but is more flexible in the choice of their shape parameters. The properties of these copulas are investigated and the elliptical copula tilting and corresponding premium are proposed as a natural tool for portfolio capital allocation. For the case of the multivariate normal family, such a tilting and premium coincide with the Esscher transform and premium.

PSARRAKOS, G. & POLITIS, K. *Monotonicity properties and the deficit at ruin in the Sparre Andersen model*. 104-118. Let $Hu(y)$ be the (proper) distribution function of the deficit at ruin, given that ruin occurs with initial surplus u , in the Sparre Andersen model of risk theory. Dickson & dos Reis (1996) discussed the monotonicity of $Hu(y)$ as a function of u . In this paper, we obtain various monotonicity results for $Hu(y)$ and other related quantities for the decreasing/increasing failure rate (DFR/IFR) and the increasing/decreasing mean residual lifetime (IMRL/DMRL) classes of distributions. These results in particular extend and make more concrete the results of Dickson & dos Reis (1996) and Willmot & Lin (1998). A new class of distributions (increasing convolution ratio; ICR) is introduced. This class extends the well-known class of distributions with IFR. Specifically, we show that if the ladder height distribution F in the model is ICR, the ratio $c(u) = F(u)$ is a non-decreasing function of u , where $c(u)$ denotes the ruin probability and $F(u) = 1 - F(u)$: Further, we obtain generalizations (expressed in terms of the distribution of the deficit) of the well-known new worse than used (NWU) property of the probability of non-ruin.

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AASE, K. K. *The Nash bargaining solution vs. equilibrium in a reinsurance syndicate*. 219-238. We compare the Nash bargaining solution in a reinsurance syndicate to the competitive equilibrium allocation, focusing on uncertainty and risk aversion. Restricting attention to proportional reinsurance treaties, we find that, although these solution concepts are very different, one may just appear as a first order Taylor series approximation of the other, in certain cases. This may be good news for the Nash solution, or for the equilibrium allocation, all depending upon one's point of view.

Our model also allows us to readily identify some properties of the equilibrium allocation not be shared by the bargaining solution, and vice versa, related to both risk aversions and correlations.

- ANDREEV, A. & SJÖHOLM, H.-K. *Projections of pension fund solvency under alternative valuation regimes*. 239-251. This paper examines the impact of three alternative valuation regimes on perceived pension fund solvency. Deterministic valuation assumes smoothed valuation of assets and liabilities. National valuation is based on market valuation of assets and on smoothed valuation of liabilities. International valuation marks assets and liabilities to market values. Using closed-form methods based on the funding ratio return, we exemplify the dramatic effect that the choice of valuation approach has on long-horizon solvency projections.
- STEFFENSEN, M. & WALDSTROM, S. *A two-account model of pension saving contracts*. 169-186. Saving contracts studied in the literature and available on the pension market share certain characteristics. An overview implies a unified formalization that exposes, at the same time, the common characteristics and the important differences. This article presents such a formalization in terms of two interacting accounts and specifies a series of examples from the literature and the market. We solve the valuation problem by derivation of a partial difference-differential equation and implementation of a numerical finite difference procedure. Illustrations are included.
- TSAI, C. C.-L. *On the ordering of ruin probabilities for the surplus process perturbed by diffusion*. 187-204. In this paper, we study orders of pairs of ruin probabilities resulting from two individual claim size random variables for corresponding continuous time surplus processes perturbed by diffusion with different premium rates, relative security loadings, and variance parameters of the diffusion processes. We show that high frequency and low severity risks yield smaller ruin probabilities than low frequency and high severity risks. These ordering relationships can also be used to obtain upper and/or lower bounds on ruin probabilities. Finally, some examples are given to illustrate the results of the theorems.
- WENG, C., ZHANG, Y. & TAN, K. S. *Ruin probabilities in a discrete time risk model with dependent risks of heavy tail*. 205-218. This paper establishes some asymptotic results for both finite and ultimate ruin probabilities in a discrete time risk model with constant interest rates, and individual net losses in the class of regular variation with index $\alpha > 0$. The individual net losses are allowed to be generally dependent while they have zero index of upper tail dependence, so that our results partially generalize the counterparts in Tang (2004). The procedure of deriving our results also demonstrates a new approach of achieving asymptotic formulation for ruin probabilities when the individual risks are dependent.

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