B.A.J. **9**, II, 481-489 (2003)

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Geneva Papers on Risk and Insurance Theory

Volume **28**(1), 2003

Garlier, G., Dana, R. A. & Shahidi, N. *Efficient insurance contracts under Epsilon-contaminated utilities.* 59-71. This paper analyses the qualitative properties of optimal contracts when agents have multiple priors and are uncertainty averse in an infinite state space framework. The case of the epsilon-contamination of a given prior, a basic tool in robustness theory is fully developed. It is shown that if both agents have strictly concave utility index, then if the insurer is less uncertainty averse than the insured, he provides a full insurance contract above a deductible for high values of the loss.

Gollier, C. *To insure or not to insure? An insurance puzzle.* 5-24. The selection of a deductible level in insurance is governed by the willingness to limit the risk borne by risk-averse agents at an acceptable cost, given the deadweight insurance loading. We examine the demand for insurance in a simple lifecycle model with a liquidity constraint and no serial correlation in the insurable risk. This allows for consumers to follow a time-diversification (self-insurance) strategy by accumulating buffer stock wealth. We conclude that insurance would only be demanded for catastrophic risks, or by people that are currently liquidity constrained. The added value of the insurance sector is thus surprisingly low in such an economy.

Li, C.-S. & Liu, C.-C. *On compulsory per-claim deductibles in automobile insurance.* 25-32. The purposes of this paper are to analyze the theoretical characteristics of the compulsory deductible system and to verify the rationality of an increasing per-claim deductible in automobile insurance. We derive the optimal variable per-claim deductible by assuming the insurers are financially balanced and the expected utility of the insured is maximized in the absence of moral hazard. Our result suggests that a variable per-claim deductible increasing with the number of claims per year is not optimal. Instead, deductibles should be charged in a decreasing rate forming second-best solution.

Machnes, Y. & Wong, K. P. *A note on deductible insurance and production.* 73-80. This paper examines the optimal production decision of a firm facing revenue risk. We show that the purchase of actuarially fair deductible insurance unambiguously induces the firm to produce more if the firm is not only risk averse but also prudent. If the firm's preferences satisfy constant absolute risk aversion, buying actuarially unfair deductible insurance unambiguously enhances production should the positive loading factor be sufficiently small. When there are moral hazard problems in that the firm's output cannot be contracted upon, we show that the purchase of actuarially fair deductible insurance unambiguously induces the firm to produce more if the firm's utility function is quadratic.

Samartín, M. *On the optimality of bank runs: comment on Allen and Gale.* 33-57. This paper presents a model consistent with the business cycle view of the origins of banking panics. As in Allen and Gale (1998), bank runs arise endogenously as a consequence of the standard deposit contract in a world with aggregate uncertainty about asset returns. The purpose of the paper is to show that Allen and Gale's result about the optimality of bank runs depends on individual's preferences. In a more general framework, considered in the present work, a

https://doi.org/10.1017/S1357321700004256 Published online by Cambridge University Press

laissez-faire policy can never be optimal, and therefore, regulation is always needed in order to achieve the first best. This result supports the traditional view that bank runs are costly and should be prevented with regulation.

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INSURANCE: MATHEMATICS & ECONOMICS

Volume **31**(3), 2002

BROUHNS, N., DENUIT, M. & VERMUNT, J. K. *A Poisson log-bilinear regression approach to the construction of projected lifetables.* 373-393. This paper implements Wilmoth's (1993) and Alho's [NAAJ, 4] recommendation for improving the Lee–Carter approach to the forecasting of demographic components. Specifically, the original method is embedded in a Poisson regression model, which is perfectly suited for age–sex-specific mortality rates. This model is fitted for each sex to a set of age-specific Belgian death rates. A time-varying index of mortality is forecasted in an ARIMA framework. These forecasts are used to generate projected age-specific mortality rates, life expectancies and life annuities net single premiums. Finally, a Brass-type relational model is proposed to adapt the projections to the annuitants population, allowing for estimating the cost of adverse selection in the Belgian whole life annuity market.

CENTENO, M. DE L. *Excess of loss reinsurance and Gerber's inequality in the Sparre Anderson model.* 415-427. Assuming that the reinsurance premium is calculated according to the expected value principle we study an upper bound for the probability of ruin in finite horizon, as function of the excess of loss retention limit. The upper bound used is an extension proved by Grandell [Aspects of Risk Theory, Springer, New York, 1991] of Gerber's bound, see Gerber [Martingales in risk theory, Mitteilungen der Vereinigung Schweizerischer Versicherungsmathematiker, 1973], for the Sparre Anderson model [On the collective theory of risk in the case of contagions between the claims, in: Proceedings of the Transactions on XV International Congress of Actuaries, New York, 1957].

CZADO, C. & RUDOLPH, F. *Application of survival analysis methods to long-term care insurance.* 395-413. With the introduction of compulsory long-term care (LTC) insurance in Germany in 1995, a large claims portfolio with a significant proportion of censored observations became available. In first part of this paper we present an analysis of part of this portfolio using the Cox [JRSS B, 34 187] proportional hazard model to estimate transition intensities. It is shown that this approach allows the inclusion of censored observations as well as the inclusion of time dependent risk factors such as time spent in LTC. This is in contrast to the more commonly used Poisson regression with graduation approach (see e.g., Renshaw and Haberman (1995)), where censored observations and time dependent risk factors are ignored. In the second part we show how these estimated transition intensities can be used in a multiple state Markov process (see Haberman and Pitacco (1999)) to calculate premiums for LTC insurance plans.

ENGLAND, P. D. *Addendum to "Analytic and bootstrap estimates of prediction errors in claims reserving".* 461-466. In England and Verrall [IME, 25], an appropriate residual definition was considered for use in a bootstrap exercise to provide a computationally simple method of obtaining reserve prediction errors for the chain ladder model. However, calculation of the first two moments of the predictive distribution only was considered. In this paper, the method

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is extended by using a two-stage process: bootstrapping to obtain the estimation error and simulation to obtain the process error. This has the advantage of providing realisations from the whole predictive distribution, rather than just the first two moments.

HESS, K. T. & SCHMIDT, K. D. *A comparison of models for the chain–ladder method.* 351-364. The chain–ladder method is the most popular method of loss reserving. In its origin, it is nothing else than a heuristic and appealing algorithm. Because of the stochastic nature of the quantities to which the algorithm is applied, several authors have studied the question whether the chain–ladder method can be justified by a stochastic model and a statistical method related to the model. In the present paper we compare a variety of such models. The comparison results in a flow chart for model selection which may help to decide in a specific situation whether the chain–ladder method should be applied or not.

HÜRLIMANN, W. *On immunization, stop-loss order and the maximum Shiu measure.* 315-325. Some main immunization results are derived in a straightforward way using some well-known equivalent characterizations of the stop-loss order by equal means, also called convex order. In a special case, the conditions by Fong and Vasicek [In: Kaufmann *et al*., Innovation in Bond Portfolio management: Duration Analysis and Immunization, 227-238] and Shiu [IME, 7], are extended to a necessary and sufficient condition for immunization under arbitrary convex shift factors of the term structure of interest rates. Based on a linear control problem with the Shiu measure as objective function, we analyze in detail the recent bounds by Uberti [IME, 21] on the change in portfolio value of Shiu decomposable portfolios under α-convex and convex-β shift factors. In particular, we determine corresponding maximal and minimax bounds using notions of absolute maximum and minimax Shiu measure. Finally, we consider partial cash flow matching immunization strategies, which allow to reduce the maximum Shiu measure over a fixed period to the maximum Shiu measure over shorter periods.

KONSTANTINIDES, D., TANG, Q. & TSITSIASHVILI, G. *Estimates for the ruin probability in the classical risk model with constant interest force in the presence of heavy tails.* 447-460. In this paper we investigate the ruin probability in the classical risk model under a positive constant interest force. We restrict ourselves to the case where the claim size is heavy-tailed, i.e. the equilibrium distribution function (e.d.f.) of the claim size belongs to a wide subclass of the subexponential distributions. Two-sided estimates for the ruin probability are developed by reduction from the classical model without interest force.

TSAI, C. C.-L. & WILLMOT, G. E. *On the moments of the surplus process perturbed by diffusion.* 327-350. In this paper we extend the results of Lin and Willmot [IME, 27] to those based on the surplus process perturbed by diffusion. We first derive the expression for the (discounted) moments of deficit at the time of ruin. An upper bound is also given if the claim size distribution function satisfies a certain condition. Next, we show that the joint moment of the penalty function and the time of ruin due to a claim satisfies a defective renewal equation and has an explicit expression; then the joint moment of the deficit at ruin and the time of ruin is just a special case by an appropriate choice of the penalty function. Finally, the moments of the time of ruin due to oscillation and caused by a claim, respectively, are studied. We also find that these two kinds of moments of the time of ruin have the same recursive expressions.

TSAI, C., KUO, W. & CHEN, W.-K. *Early surrender and the distribution of policy reserves.* 429-445. We extend the literature by incorporating early surrender into the distribution estimation for policy reserves. First, we employ the cointegrated vector autoregression technique to estimate an empirical relation between the lapse rate and interest rate. The tests indicate a significant cointegrated vector that implies a long-term relation between the lapse rate and interest rate. Based on the estimated error-correction model, we then simulate the

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policy reserve distribution with stochastic mortality, interest rate, and early surrender. We find that early surrender reduces the expected value as well as the risk for policy reserves due to surrenders in the low interest rate periods. Further analyses indicate that the early surrender effect depends on the sign and magnitude of the difference between the market interest rate and policy credit rate. When the credit rate is higher (lower) than the market interest rate, early surrender acts to decrease (increase) the mean reserve. This effect increases with the magnitude in the difference.

WAGNER, C. *Time in the red in a two state Markov model.* 365-372. Consider a discrete time risk process based on a two state Markov chain. The premium is assumed to be the reciprocal of an integer, the benefit is unity and the initial surplus is a multiple of the premium. We will derive recursion formulae for the joint distribution of ruin and severity of ruin and for the expected time to surplus zero from a given negative surplus. Further we will derive asymptotic estimates for the ruin probability, the severity of ruin and their joint distribution. In conclusion we will calculate the expected time in the red.

INSURANCE: MATHEMATICS & ECONOMICS

Volume **32**(1), 2003

BOLANCÉ, C., GUILLÉN, M. & NIELSEN, J. P. *Kernel density estimation of actuarial loss functions.* 19-36. In this paper we estimate actuarial loss functions based on a symmetrized version of the semiparametric transformation approach to kernel smoothing. We apply this method to an actuarial study of automobile claims. The method gives a good overall impression while estimating actuarial loss functions, since it is capable of estimating both the initial mode and the heavy tail that is so typical for actuarial and other economic loss distributions. We study the properties of the transformation kernel density estimation and show the differences with the multiplicative bias corrected estimator. We add insight into the kernel smoothing transformation method through an extensive simulation study with a particular view to the performance of the estimation at the tail.

BRAZAUSKAS, V. *Influence functions of empirical nonparametric estimators of net reinsurance premiums.* 115-133. In this paper we illustrate the usefulness of influence functions for studying robustness properties of empirical nonparametric estimators of net premiums of various reinsurance treaties. (Proportional, stop-loss, excess-of-loss, largest claims, and excédent du coût moyen relatif [ECOMOR] type reinsurance treaties are considered.) We use the gross error sensitivity (GES) and the upper breakdown point (UBP) as robustness criteria. It is found that empirical nonparametric estimators are not robust with respect to GES and UBP. Alternative methods of estimation are suggested.

CAI, J. & DICKSON, D. C. M. *Upper bounds for ultimate ruin probabilities in the Sparre Andersen model with interest.* 61-71. We consider the Sparre Andersen model modified by the inclusion of interest on the surplus. Exponential type upper bounds for the ultimate ruin probability are derived by martingale and recursive techniques. Applications of the results to the compound Poisson model are given. Numerical comparisons of upper bounds derived by each technique are presented.

CHENG, Y. & PAI, J. S. *On the* n*th stop-loss transform order of ruin probability.* 51-60. The concept of the *n*th stop-loss order is generalized to the class of general nonnegative monotone decreasing functions. The *n*th stop-loss transform of the first deficit below its initial level is expressed in terms of the *n*th stop-loss transform of the claim amount random variable. We study the stop-loss ordering of ruin probability through the maximal aggregate loss and obtain a result relating the stop-loss ordering of ruin probabilities to the stop-loss ordering of severities.

https://doi.org/10.1017/S1357321700004256 Published online by Cambridge University Press

De Gooijer, J. G. & Vidiella-I-Anguera, A. *Nonlinear stochastic inflation modelling using SEASETARs.* 3-18. The development of stochastic inflation models for actuarial and investment applications has become an important topic to actuaries since Wilkie [TFA 39] introduced his first investment model. Two empirical features of monthly inflation rates are dynamic dependence on the level of the series and seasonal fluctuations. We propose a model, termed multiplicative seasonal self-exciting threshold autoregressive (SEASETAR), which captures both features simultaneously. The model is a special case of a general non-multiplicative SETAR model. The usefulness of multiplicative SEASETAR models is demonstrated by analyzing five data series of monthly inflation rates. One of these series corresponds to a country with hyperinflation episodes. To get a better understanding of the basic features underlying the fitted SEASETAR models we also perform a dynamic analysis.

Fischer, T. *Risk capital allocation by coherent risk measures based on one-sided moments.* 135-146. This paper proposes differentiability properties for positively homogeneous risk measures which ensure that the gradient can be applied for reasonable risk capital allocation on non-trivial portfolios. It is shown that these properties are fulfilled for a wide class of coherent risk measures based on the mean and the one-sided moments of a risky payoff. In contrast to quantile-based risk measures like Value-at-Risk (VaR), this class allows allocation in portfolios of very general distributions, e.g. discrete ones. Two examples show how risk capital given by the VaR can be allocated by adapting risk measures of this class to the VaR.

Frostig, E. *Ordering ruin probabilities for dependent claim streams.* 93-114. Claims arriving to an office can be of several types. Due to different types of catastrophes or shocks, different types of claims might arrive at the same time. This phenomena imposes dependence among claims arrival streams of different types. We show that when the dependence among arrival streams increases, the ruin probability also increases. We consider the compound Poisson model. We extend and generalize results obtained by Cossette and Marceau [IME, 26].

Genest, C., Marceau, É. & Mesfioui, M. *Compound Poisson approximations for individual models with dependent risks.* 73-91. This paper shows how compound Poisson distributions can be used to approximate the distribution of the total claim amount in the context of single- or multi-class individual risk models where dependence between the contracts arises through mixtures. Some of these models are generated by Archimedean copulas, and others are seen to fall under the purview of a general multi-class shock model whose structure is both intuitive and easily tractable. A numerical study is used to illustrate the quality of the approximation as a function of the heterogeneity and the dependence in the portfolio. A theoretical result is also provided which helps to explain the effect of dependence on the total claim amount when the contracts are linked through an Archimedean copula model.

Hashorva, E. *On the number of near-maximum insurance claim under dependence.* 37-49. Let $X_1, X_2 \ldots$ be random claim sizes with continuous distribution functions F and $N(\cdot)$ an independent point process on $[0, \infty)$. Denote by $X_{N([0,t]):N([0,t])}$ the maximal claim size occurring during the time interval $[0, t].t > 0$ and $\mathcal{K}_t(a)$ the number of claims that excess the random barrier $X_{N([0,t])} - a_t$, with $a_t > 0$. For iid claim sizes, both distributional and asymptotic properties of $\mathcal{K}_t(a)$ are investigated in Li and Pakes (2001) [Li, Y., Pakes, A.G., Insur.: Math. Econ. 28 (3), 309-323]. In this paper, by dropping the iid assumption we extend and simplify limit results of Li and Pakes (2001). Further, we show that $\mathcal{K}_t(a)/t$ is a strongly consistent estimator of certain tail probability.

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https://doi.org/10.1017/S1357321700004256 Published online by Cambridge University Press

JOURNAL OF RISK AND INSURANCE

Volume **70**(1), 2003

BROWN, J. R. *Redistribution and insurance: mandatory annuitization with mortality heterogenity.* 17-41. This article examines the distributional implications of mandatory longevity insurance when mortality heterogeneity exists in the population. Previous research has demonstrated the significant financial redistribution that occurs under alternative annuity programs in the presence of differential mortality across groups. This article embeds that analysis into a life-cycle framework that allows for an examination of distributional effects on a utility-adjusted basis. It finds that the degree of redistribution that occurs from the introduction of a mandatory annuity program is substantially lower on a utility-adjusted basis than when evaluated on a purely financial basis. In a simple life-cycle model with no bequests, complete annuitization is welfare enhancing even for those with higher-than-average expected mortality rates, so long as administrative costs are sufficiently low. These findings have implications for policy toward annuitization, particularly as part of a reformed Social Security system.

CAMPBELL, C. J., GOLDBERG, L. & RAI, A. *The impact of the European Union insurance directives on insurance company stocks.* 125-167. This article examines the impact of the passage of the Second and Third Life and Non-Life European Insurance Directives on insurance firms located in 14 European Union countries, Norway, and Switzerland. The third directives have a wealth effect on the European insurance market, while the second directives do not. The Third Life Directive resulted in a wealth increase for the European insurance market, while the Third Non-Life Directive had a modest negative wealth effect. The wealth effects differ at both the country and firm level. The directives have differential impacts on firms depending on the firms' characteristics and those of the market they operated in prior to the directives. Regression results indicate that the second directives have impacted firms in protected markets negatively, especially those with higher debt and higher returns on assets. At the time of the third directives, insurance firms benefited, even those in previously protected markets, indicating that firms may have positioned themselves in preparation for the liberalization of the laws.

CARDON, J. H. & SHOWALTER, M. H. *Flexible spending accounts as insurance.* 43-51. We model flexible spending accounts (FSAs) as a special type of insurance policy. We prove the following results given losses drawn from a continuous distribution: (1) the optimal election amount, F^*, is increasing in the consumer's level of risk aversion; (2) F^* is increasing in the level of the maximum loss. If utility is decreasing in absolute risk aversion (DARA), then F^* is (3) decreasing in income and (4) increasing in the marginal tax rate.

EWING, B. T., PIETTE, M. J. & PAYNE, J. E. *Forecasting medical net discount rates.* 85-95. Determining the present value of future medical costs is an important issue for a variety of public and private entities. This article examines the time-series properties of medical net discount rates and considers the implications for forecasting. The article provides evidence that the standard autoregressive moving average forecasting model may be improved by modeling the time-varying volatility characteristics of the medical net discount rates.

FANG, Y. *Semi-parametric specification tests for discrete probability models.* 73-84. Loss functions play an important role in analyzing insurance portfolios. A fundamental issue in the study of loss functions involves the selection of probability models for claim frequencies. In this article, we propose a semi-parametric approach based on the generalized method of moments (GMM) to solve the specification problems concerning claim frequency distributions. The GMM-based testing procedure provides a general framework that

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encompasses many specification problems of interest in actuarial applications. As an alternative approach to the Pearson χ^2 and other goodness-of-fit tests, it is easy to implement and should be of practical use in applications involving selecting and validating probability models with complex characteristics.

HUNTER, G. *Incomplete markets and hyperbolic discounting.* 97-109. A growing number of empirical researchers are finding evidence of hyperbolic discounting in their investigations on the nature of preferences for distributing consumption over time. This article contributes to the literature by exposing a large class of models in which hyperbolic and exponential discounting are observationally equivalent. The results of the modeling approach simultaneously resolve serious concerns raised by other models in the literature that have been used to explain the empirical findings and answer other questions raised by the phenomenon that are unexplained by earlier contributions. By analyzing an intertemporal general equilibrium model with incomplete insurance markets, this article demonstrates that for sufficiently short time horizons, values implied by a hyperbolic discount function fall within incomplete market valuation bounds.

KELLY, M. & KLEFFNER, A. E. *Optimal loss mitigation and contract design.* 53-72. This work examines the interaction between the premium rates set by an insurer and the incentives of an individual to purchase market insurance and undertake mitigation to reduce the size of a potential loss. A risk-neutral monopolistic insurer prices insurance according to the price-elasticity of demand for coverage. The elasticity of demand is affected by the presence of both mitigation and government intervention. The availability of loss reduction activities increases the consumer's elasticity of demand and lowers the optimal rate charged by the monopolist. Government intervention reduces both expenditures on mitigation and the rate charged by the monopolistic insurer.

LACHANCE, M.-E., MITCHELL O. S. & SMETTERS, K. *Guaranteeing defined contribution pensions: the option to buy back a defined benefit promise.* 1-16. After a long commitment to defined benefit (DB) pension plans for U.S. public sector employees, many state legislatures have introduced defined contribution (DC) plans for their public employees. In this process, investment risk that was previously borne by state DB plans has now devolved to employees covered by the new DC plans. In light of this trend, some states have introduced a guarantee mechanism to help protect DC plan participants. One such guarantee takes the form of an option permitting DC plan participants to buy back their DB benefit for a price. This article develops a theoretical framework to analyze the option design and illustrate how employee characteristics influence the option's cost. We illustrate the potential impact of a buy-back option in a pension reform enacted recently by the State of Florida for its public employees. If employees were to exercise the buy-back option optimally, the market value of this option could represent up to 100 percent of the DC contributions over their work life.

WANG, H. H. & ZHANG, H. *On the possibility of a private crop insurance market: a spatial statistics approach.* 111-124. Risk theory tells us if an insurer can effectively pool a large number of individuals to reduce total risk, the insurer can then provide insurance by charging a premium close to the actuarially fair rate. However, a common belief exists that risk can be effectively pooled only when random loss is independent. Therefore crop insurance markets cannot survive without government subsidy because crop yields are not independent among growers. In this article, we take a spatial statistics approach to examine the effectiveness of risk pooling for crop insurance under correlation. We develop a method for evaluating the effectiveness of risk pooling under correlation and apply the method to three major crops in the United States: wheat, soybeans, and corn. The empirical study shows that yields for the three crops present zero or negative correlation when two counties are far apart, which

https://doi.org/10.1017/S1357321700004256 Published online by Cambridge University Press

complies with a weaker condition than independence, finite-range positive dependency. The results show that effective risk pooling is possible and reveal a high possibility of a private crop insurance market in the United States.

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NORTH AMERICAN ACTUARIAL JOURNAL

Volume **7**(1), 2003

CHENG, Y. & TANG, Q. *Moments of the surplus before ruin and the deficit at ruin in the Erlang(2) risk process.* 1-12. This paper investigates the moments of the surplus before ruin and the deficit at ruin in the Erlang(2) risk process. Using the integro-differential equation that we establish, we obtain some explicit expressions for the moments. Furthermore, when the claim size is exponentially and subexponentially distributed, asymptotic relationships for the moments are derived as the initial capital trends to infinity. Also, we show the joint probability density function of the surplus before ruin and the deficit at ruin.

FREES, E. W. *Multivariate credibility for aggregate loss models.* 13-37. Credibility is a form of insurance pricing that is widely used, particularly in North America. It is a special type of experience rating that employs a weighted average of claims experience and a previously established price to determine a new price for each risk class under consideration. This article extends traditional credibility formulas in two aspects. The new procedures are called 'multivariate credibility' because both aspects make use of additional sources of data when compared to traditional formulas. Specifically, the first portion of the paper considers data from both the claims number and claims amount processes. Assuming an aggregate loss model for total claims, optimal insurance pricing formulas are derived. The insurance prices turn out to be an intuitively appealing weighted average of the overall mean claim, the claims number experience, and the claims amount experience. The second portion of the paper considers data from claims number and amount processes from multiple lines of business. By using covariances among lines of business (that are conditional on the unobserved heterogeneity), this article shows how to derive more efficient insurance prices. Accounting for covariance among different random quantities (securities) is standard practice in the investment industry. It is more difficult in an insurance context because of the heterogeneity associated with different kinds of risk classes. Nonetheless, ignoring this covariance has important ramifications, both theoretically and practically. For an illustrative sample of Massachusetts automobile claims, we show that the relative differences in accounting for and ignoring the covariance range from −3.9% to 14.5% for a selected bundle of insurance coverages.

GERBER, H. U., LEUNG, B. P. K. & SHIU, E. S. W. *Indicator function and Hattendorff theorem.* 38-47. This paper presents an integration-by-parts proof of the Hattendorf theorem in the general fully continuous insurance model. The proof motivates a derivation of the theorem in the general fully discrete insurance model. Increments of a martingale over disjoint time intervals are uncorrelated random variables; the paper explains that the Hattendorff theorem can be viewed as an application of this result. A noticeable feature of the paper is the extensive use of the indicator function.

GERBER, H. U. & SHIU, E. S. W. *Pricing lookback options and dynamic guarantees.* 48-67. This paper is motivated by the problem of pricing exotic options or guarantees in equity-indexed

https://doi.org/10.1017/S1357321700004256 Published online by Cambridge University Press

annuities. It presents closed form formulas for pricing lookback options and dynamic guarantees. Closed-form pricing formulas facilitate the hedging and reserving for such products. The principal tool is a closed form expression for $B(u, T)$, the Laplace-Stieltjes transform of the expected excess of the running maximum of a Wiener process above a positive constant u in a finite time interval of length T. If we model the aggregate net income of a company with a Wiener process, then the excess of the running maximum above u can be interpreted as aggregate dividend payments, and the quantity $B(u, T)$ is the expectation of the discounted value of the dividend payments up to time T. The formula for $B(u, T)$ is used to price European lookback options (call and put, fixed and floating strike). It is also used to price dynamic fund protection, which is a guarantee on an investment fund: the number of units of the investment fund is increased whenever necessary, so that their total value does not fall below a guaranteed level. The guaranteed level can be stochastic, such as that given by a stock index. Some well-known results for the first passage time of the Wiener process are explained in the Appendix for the convenience of the reader.

YOUNG, V. R. *Equity-linked life insurance: pricing and reserving using the principle of equivalent utility.* 68-86. The author applies the principle of equivalent utility to price and reserve equity-indexed life insurance. Young and Zariphopoulou (2002a, b) extended this principle to price insurance products in a dynamic framework. However, in those papers, the insurance risks were independent of the risky asset in the financial market. By contrast, the death benefit for equity-indexed life insurance is a function of a risky asset; therefore, this paper further extends the principle of equivalent utility. In a second extension, the author applies the principle of equivalent utility to calculate reserves, as introduced by Gerber (1976). In a related paper, Moore and Young (2002) price equity-indexed pure endowments, the building blocks of equity-indexed life annuities.

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