1. Actuarial Science
Programme leader: Prof. dr H. Wolthuis

Department: Quantitative Economics (KE)

2. No Subprogrammes

3. Programme members:

Prof. drs B.J.J. Alting von Geusau	(1996-1999)	(hgl)
Dr J. Bogers	(1996-	(ud)
Dr D.R Dannenburg	(1997-1998)	(ud)
Prof. dr J. Dhaene	(1997-2000)	(hgl)
Prof. dr M.J Goovaerts	(1996-2000)	(bijz.hgl)
Dr A.E. van Heerwaarden	(1999-2000)	(ud/uhd)
Dr R. Kaas	(1996-2000)	(uhd)
Prof. drs C.L. Smid	(1996-1999)	(hgl)
Dr J. Spreeuw	(1999)	(postdoc)
Prof. dr J. Vermaat	(2000)	(hgl)
Prof. dr F.E.C. de Vylder	(1998-2000)	(hgl)
Prof. dr H.Wolthuis	(1996-2000)	(hgl)

4. Key words:

- Actuarial Models
- Financial Institutions
- Financial Risks
- Insurance
- Stochastic Cash Flows

5. Research input of academic staff

Fte		1996	1997	1998	1999	2000	Total
wp1	Ph.D.	0.60	0.60	0.60	0.20	-	2.00
	Other	1.36	1.20	1.28	1.31	1.6	6.75
wp2	OIO	-	-	-	-	-	-
	Other	-	-	-	-	-	-
wp3	AIO	-	-	-	-	-	-
	Other	0.20	0.52	0.26	0.18	0.21	1.37
Total		2.16	2.32	2.14	1.69	1.81	10.12

Main source(s) for contract and similar research:
Stichting Verzekeringswetenschap

6. Research output

			1996	1997	1998	1999	2000	Total
Dissertation			1			1		2
Academic Publications	International journal articles	Refereed	3	9	7	12	6	37
		Non-refereed	1	4		1	2	8
	Other academic publications	Books			1			1
		Chapters			1	3		4
		Proceedings		1	5	1	4	11
	Dutch publications	Refereed	1			1		2
		Non-refereed		1			1	2
Professional publications and scientific reports for third parties			3	5	6	3	9	26

7. Composition of research input academic staff 2000

Fte	wp1	Wp2	wp3	Total
Prof.'s	0.13	-	0.21	0.34
Ass. Prof.'s	0.92	-	-	0.92
Postdocs	0.55	-	-	0.55
Ph.D.'s	-	-	-	-
Total	1.60	-	0.21	1.81

8. Programme design in brief

The programme concerns both fundamental and applied research in the field of financial institutions, for the moment mainly directed at insurance, social insurance included, but in the future also at banks and other financial institutions. (Formerly well delimited and compartmentalised, the activities of the financial sectors - banks, insurance companies, credit institutions, etc. - are increasingly tending to interpenetrate, be it on the macroeconomic level through the appearance of vast financial conglomerates, or at the marketing level through the development of mixed products.) The research is mainly directed at the mathematical modelling, estimation, appraisal, and control of *financial risks* of financial institutions (for insurers in the field of life, non-life and pension insurance) under complete and incomplete information. For long term insurance contracts, especially pensions, saving by insurance is significant, which leads to accompanying investment problems. This for instance concerns the "tuning" of the insurance and investment portfolios. Another practical aspect is the influence of the "risk of longevity" on the policies of life insurance, social insurance and care insurance. This remains a permanent subject of investigation. Present-day problems of insurance companies concern decreasing profit margins, increasing competition and selective behaviour of the insured and of insurance companies. Up to now limited attention has been given to problems that emerge from the privatisation of social insurance. The research partly deals with problems related to the supervision of insurance companies.

An important subject of investigation is the further development of actuarial risk theory, in particular the development of new mathematical and economic models in the fields of mathematical reserves, equalisation reserves and solvency margins for insurance portfolios. Other significant fields of research are the interaction between credibility theory, models for the estimation of unreported claims (IBNR) and actuarial ordering of risks, and the consequences for the determination of insurance and tariff premiums. In the premium calculation and tarification of insurance, the determination of the factors that are relevant for the risk (risk classification) is a significant aspect. Other aspects for the premium calculation are the homogeneity and heterogeneity of the insurance portfolios, the solidarity between the insured, the voluntary or compulsory character of the insurance, and the auto selection and anti-selection of those insured. Another theoretical research subject concerns the unification of several distinct actuarial theories in the field of non-life, life and pension insurance, partly in connection with stochastic financial mathematics.

9. Substantive overview of results

Credibility theory, General Linearized Models and applications

One of the techniques that can be considered typically non-life actuarial is experience rating by credibility theory. It provides us with techniques to determine insurance premiums for contracts in a heterogeneous portfolio, in case there is limited or irregular claims experience available for each contract, but ample experience for the whole portfolio. Premiums are in this case calculated as a weighted average between collective and individual experience with the contracts in a portfolio. In other

disciplines such as biometrics and econometrics, models have been developed quite similar to those of credibility theory. Though essentially a classical statistical method, credibility theory has a Bayesian orientation, but closely related variance components models stem from classical statistics. In the evaluation period a PhD thesis (Dannenburg (1996)) and a textbook (Dannenburg, Kaas, Goovaerts (1996)) appeared that were entirely devoted to this subject. The thesis e.g. investigates some new and potentially useful models such as the two-way crossed classification model. The assumption that the risks between two different observation periods are stochastically dependent is relaxed by using the two-way classification model. In the thesis the credibility model is also extended to an autoregressive credibility IBNR (Incurred But Not Reported) model by extending the model of De Vylder and Mack. It is concluded that even in basic credibility models much can be done to improve their practical usefulness. Though a lot of research remains to be done to improve the applicability of credibility models, the number of publications on these models has decreased in the last years; the research group only produced papers on credibility connected with weighted observations (Kaas, Dannenburg, Goovaerts (1997)) and spline theory (De Vylder (1998)). Other techniques like General Linearized Models have been used recently by the research group to tackle e.g. the IBNR problem (Dannenburg, Kaas, Usman (1998)). In a recent paper on the distribution of IBNR reserves random fluctuations in the direction of calendar years is modelled (Goovaerts, Redant (1999)), taking into account the apparatus of financial mathematics. The results are general in the sense that all possible dependencies between variables are allowed for. An earlier paper deals with IBNR reserves under stochastic interest rates (Goovaerts, De Schepper (1997)).

Ordering of risks and dependency of risks

This subject is in fact the research subject in which nearly all research members are involved. Looking back over the reviewing period, ordering of risks and dependencies of risks are getting more and more attention in the research programme. In the period before this overview two PhD theses have appeared in which ordering of risks played a major role. Here e.g. concepts like stop-loss order, convex order and stochastic order are relevant. The emphasis in the last years is getting increasingly directed towards dependencies of risks (e.g. the mortality rates depend on each other for married couples), partly based on earlier results on the theory of ordering of risks (Goovaerts and Dhaene (1996), Dhaene & Denuit (1999) and Denuit & Dhaene (2000)). Several possible defence structures exist, and have been investigated; for instance dependencies for a simple widows' pension (Dhaene, Vanneste & Wolthuis (2000)). Presently, in many papers, the defence structure called comonotonicity is considered, since this is the strongest possible dependence structure in view of the marginal distributions. For example, lower and upper bounds of distribution functions and sums of random variables were derived mainly for the field of non-life insurance (Kaas, Dhaene & Goovaerts (2000), Goovaerts, Dhaene & De Schepper (2000)). Comonotonicity was e.g. studied in relation to non-life premium principles (Wang & Dhaene (1998)). Stochastic calculations and approximations of distributions of the present value of cash flows based on deterministic or stochastic interest were studied in many papers (see under heading Stochastic interest). For the comonotonic case the distribution function was derived for the disability insurance, framed in a multistate model of life insurance (Spreeuw (2000)). The practical relevance is that distributions of risk, related premiums and reserves can be calculated more easily, either saving computing time (if upper or lower bounds are considered), or with more accuracy (if a

relevant dependence structure of risks is adopted that is closer to reality than the usual independence assumption still often used in practice). Dependency of risk in connection with stop-loss order was studied in Dhaene & Goovaerts (1997) and in connection with the individual life model in Dhaene & Goovaerts (1997). The theory is also relevant for problems in financial economics, as has been demonstrated in a recent article (Simon, Dhaene & Goovaerts (2000)) that computes upper bounds for the price of an arithmetic Asian option.

Stochastic interest

In financial mathematics and life insurance fixed interest assumptions are increasingly being replaced by models based on random interest assumptions; in non-life actuarial models interest is modelled as a new factor. The already mentioned non-life actuarial paper Goovaerts & De Schepper (1997) considers IBNR reserves under stochastic interest. In the field of financial mathematics Schepper, Goovaerts & Kaas (1997), Vanneste, Goovaerts, De Schepper & Dhaene et al (1997), Goovaerts (1998), De Schepper, Goovaerts & Heijnen (1999) and Cosette, Denuit, Dhaene & Marceau (2000) are papers dealing with the calculation or approximation of present value functions (like perpetuities and annuities) under stochastic interest rates. Goovaerts & Dhaene (1999) and two other earlier mentioned recent papers (Goovaerts, Dhaene & De Schepper (2000) and Kaas, Dhaene & Goovaerts (2000)) combine the subject of stochastic present value functions (like annuities) with special types of ordering and dependency of risks.

Homogeneity and heterogeneity

In non-life actuarial science most models are based on the concept of heterogeneity, but some research has been done for homogeneous risk models with equalised claim amounts (De Vylder & Goovaerts (2000)). In life insurance, traditionally premiums and reserves are based on the concept of homogeneity, and all present textbooks in this field are still based on this concept. In the reviewing period much work has been done to consider several problems related to (unobserved) heterogeneity in life insurance mathematics. This is connected to the concept of hazard rate (the probability of a certain event occurring at some point of time, conditional on what has happened before that time). For instance solidarity measures taken from non-life insurance have been introduced for the life case and especially the Markov model (Spreeuw (1996), Spreeuw & Wolthuis (1997) and Spreeuw (1999)). In connection with this profit sharing is also considered for a simple two-state model (life and death). The research of Spreeuw (1999) partly moved into the field of mathematical economics where aspects of symmetry and asymmetry of information were investigated, and into the field of non-life insurance where hazard rates were used to predict claim numbers (see also Spreeuw & Goovaerts (1998)).

Multistate models

These are typically long term models used in life insurance and disability insurance (also AIDS and dread disease models are special cases) based on compound interest and probability distributions. One chapter of the earlier mentioned PhD thesis on heterogeneity of hazard rates in insurance, introduces concepts like probabilistic and subsidising solidarity for the hierarchical Markov model (see also Spreeuw & Wolthuis (1997)), and connects this with the well-known concept of the actuarial loss function. Also papers appeared on special cases of the multi-state models. For instance, the mentioned paper on dependencies of the widows' pension (Dhaene,

Vanneste & Wolthuis (2000)) and the introduction of the concept of comonotonicity in a special type of disability insurance model (Spreeuw (2000)). A PhD research proposal was written and approved by the faculty, to more deeply consider the problem of random interest in multi-state life models, but -until now- this project is still open for applicants.

Reserving and solvency

The subject is of course still a very important one and has partly been considered under the headings of earlier subjects. Explicitly only two papers on solvency margins and equalisation reserves appeared (Wolthuis (1996) and De Vylder & Goovaerts (1998)). In the reviewing period a congress volume of a symposium held on this subject, organised by the research group in co-operation with the supervisory authorities and Erasmus University, appeared. Also an updated second edition of a book on Reserving and Solvency in the EC was published (Wolthuis & Goovaerts, ed. (1997)). Recently, in this field, a part-time professor on supervision of insurance companies and pension funds was appointed.

Integration of theories of life and non-life insurance

Inspired by a paper of Jewell (1980), the research group is the only one in the university with a long tradition of integrating the theories and models of life and non-life insurance. This is again demonstrated for the reviewing period in the above results.

Other

For classical ruin theory e.g. inequality extensions of Prabhu's formula were derived (De Vylder & Goovaerts (1999)), also some other papers dealt with this subject (De Vylder & Goovaerts (1998, 1999)). Several textbooks appeared: two in the field of life insurance mathematics (Wolthuis & Bruning (1996) and Wolthuis (1997)) and two in the field of non-life insurance (Dannenburg, Kaas & Goovaerts (1996) and Kaas & Goovaerts (1998)). Although the textbooks are mainly relevant to actuarial education, this is a necessary part of the research groups activities since only a limited number of suitable actuarial text books are available. One reason is that the number of universities in the world with a complete university actuarial science program is rather limited (in the Netherlands there is for instance only one such program). Another reason is that our actuarial program is part of an economics faculty instead of a faculty of mathematics (and statistics), which is normally the case. This means that we are to a high degree responsible for our own educational material. Note that the textbooks produced at the UvA undeniably also have an impact on actuarial research. For instance, the book *Ordering of Actuarial Risks* (Kaas, Van Heerwaarden & Goovaerts, 1994) is cited very often in actuarial papers. The celebration of the 50th anniversary of actuarial education at the UvA led to the publishing of two other books (Wolthuis & Goovaerts, ed. (1998)).

10. Programme development

It seems that problems that were once tackled with credibility theory will in the future be resolved using more econometric and statistical models like Generalised Linear Models (GLIM); a number of chapters for a textbook on those models have been written, but the subject will be more educational than research oriented. As mentioned

under 9, the main focus of the research of the group presently is on the subject of ordering of risks and dependence of risks. It is expected that this will continue to be a fruitful field of research in the coming years and that a large part of the group's efforts will be put in that direction. In co-operation with the professors of financial economics and financial econometrics a new PhD research project will be started soon. This project, called "Valuation of Interest Guarantees in Insurance Projects", demonstrates the integration of actuarial and financial modelling. A second PhD project, that will be submitted in the near future, is "Reinsurance and Insurance Linked Derivatives", hence, also a project that combines insurance and financial market elements. Other mentioned subjects will probably get less attention.

In the field of actuarial science and actuarial practice, as mentioned, traditionally only insurance risks were considered, but as things develop presently more attention will be paid to both sides of the balance sheets of insurance companies and pension funds, or more general, financial institutions. This will lead to a future major change in the actuarial education programme, with many courses in the field of financial economics, like finance, investment and option theory. A part-time professor will be hired to cover the combined field called asset and liability management (ALM).

Another thing is that valuation of future liabilities that were traditionally based on discounting of (random) cash flow using a safe low rate of interest will in the future be determined by market values of those cash flows. This will be done for both the asset and liability sides of the balance sheet. The International Accounting Standards Board, the Dutch Central Bank and the Supervisory authorities of Pension & Insurance are already convinced of the necessity of this valuation scheme. This will certainly lead to research in this new direction. Of course, close co-operation with financial economists of the UvA or other universities will be required. After the new professor in ALM has been appointed an additional research subprogramme will have to be formulated (the concept is already available). In other countries, of course, the same issues exist. We are happy to mention that two universities of Belgium with whom we closely co-operate have already an approved research programme in this new direction, also with participating financial economists.

In the coming period of five years several professors will retire (Smid, Vermaat and De Vylder); this will only have an influence of about 10% of the research output. A new staff member will fill this gap.

11. Societal/technical relevance

Insurance companies, pension funds and consultancy firms need actuaries and actuarial research in their daily work in estimating risks, calculation of premiums and reserves, and actuarial analysis of insurance portfolios. Actuarial science is a field of with applications in the insurance and the financial industry. Part of the research programme is directed towards practical applications.

The research group regularly participates in the dissemination of research findings to actuaries working in practice by participating in the Permanent Education courses of the Dutch Actuarial Society; subjects include self-selection, financial reinsurance, and the ordering and dependency of risks.

Several conferences were held on the broader field of insurance together with the Dutch supervisory authorities and Erasmus University Rotterdam. Subjects at these conferences included: "Premium Differentiation and Solidarity", "Solvency", and "Future-Strategies of the Financial Service Industry: Integration or Polarisation".

In 1998 a conference was held called "The Taming of Risks in the 21st Century" aimed at Dutch actuaries working in practices, on the occasion of the 50th anniversary of actuarial education at the University of Amsterdam. As mentioned, two books were published, one with historical papers and one with popular papers in the field of actuarial science.

12. Other indications of quality and reputation

Visiting positions
Guest professorships in actuarial science at the Katholieke Universiteit Leuven (Kaas and Wolthuis) and the University of Economic Sciences, Budapest (Wolthuis and Spreeuw).

Invited addresses, keynote speeches
De Vylder was invited keynote speaker of several IME conferences.

Editorial board positions (editor, associate editor, editorial board member, etc.)
- Members of the research group are editor, managing editor and associate editor (respectively, Goovaerts, Kaas and Wolthuis) of the periodical *Insurance: Mathematics & Economics*, the only actuarial journal categorised A.
- Goovaerts is co-founder of *the Journal of Computational and Applied Mathematics* and is member of the editorial board of the *ASTIN Bulletin*.

Awards and prizes
- Former PhD-student Dannenburg won the first price for young scientist at the 25th International Congress of Actuaries with his article "Crossed Classification Credibility Models".
- Goovaerts occupied the Belgian Francqui Chair 1997-98 at the Faculty of Sciences, Universiteit Antwerpen.

Conference involvement (programme committee, etc.)
- Goovaerts was chairman of the research committee of the 25th International Congress of Actuaries.
- Goovaerts and Kaas have initiated a series of international scientific conferences on *Insurance: Mathematics & Economics*. The first was held in Amsterdam (1997), but they still are closely involved in the organisation of the other conferences.

Scholarships and grants
- Together with two Belgian universities a grant of $ 12.700 was obtained for the project Actuarial aspects of dependencies in insurance portfolios (1999 International Grants Competition of the Actuarial Education and Research Fund, Society of Actuaries Committee on Knowledge Extension Research, USA).

Network positions (fellows, etc)
Goovaerts is a fellow of the Tinbergen Institute.

Referee work
Referees for several actuarial journals (Bogers, Goovaerts, Kaas, Spreeuw, van Heerwaarden, and Wolthuis).

Other
- Dannenburg received his PhD degree in actuarial science in 1996 *cum laude*.
- The research productivity of individual authors and of universities in the field of Risk and Insurance over the period 1987-1996 was studied in *The Journal of Risk and Insurance* (USA), 1998, 65, 711-741. Several rankings of authors were given. Goovaerts, Kaas and De Vylder have, see Table 9, rank 1, 10 and 13, respectively (impact weighted, not adjusted for co-authorship) and rank 1, 2 and 12, respectively (non-impact-weighted, not adjusted for co-authorship). Adjusted for co-authorship and impact-weighted Goovaerts has rank 4 and Kaas rank 22. The research group also has good ranks in Europe, only preceded by the Katholieke Universiteit Leuven and (dependent on the criteria) City University London.
- Recently a research project, called "The Theory of Dependency Applied to Asset Liability Modelling" for a new actuarial postdoc was approved by NWO.

13. Five key publications

Dannenburg, D. (1996). *Basic actuarial credibility models - evaluations and extensions*. Amsterdam: Thesis Publishers. [Promotores M.J. Goovaerts & R. Kaas] [cat A].

Vylder, F. De, Goovaerts, M.J. & Marceau, E. (1997). The Bi-atomic uniform extremal solution of Schmitters's problem. *Insurance: Mathematics & Economics, 20,* 59-78.

Dhaene, J. & Sundt, B. (1998). On approximating distributions by approximating their De Pril transforms. *Scandinavian Actuarial Journal,* 1-23.

Spreeuw, J. (1999). *Heterogeneity of Hazard Rates in Insurance.* Tinbergen Institute Research Series. Amsterdam: Thela Thesis. [Promotores H. Wolthuis & M.J. Goovaerts] [cat A].

Kaas, R., Dhaene, J. & Goovaerts, M.J. (2000). Upper and lower bounds or sums of random variables. *Insurance: Mathematics & Economics, 27,* 151-168.

14. Dissertations

Dannenburg, D. (1996). *Basic actuarial credibility models - evaluations and extensions.* Universiteit van Amsterdam. Amsterdam: Thela Thesis. [Promotores M.J. Goovaerts & R. Kaas] [cat. A].

Spreeuw, J. (1999). *Heterogeneity of Hazard Rates in Insurance.* Universiteit van Amsterdam. Tinbergen Institute Research Series. Amsterdam: Thela Thesis. 178 pages [Promotores H. Wolthuis & M.J. Goovaerts] [cat. A].

15. Academic publications

Academic publications (excluding publications in/of books) – refereed
1996

Goovaerts, M.J. & Dhaene, J. (1996). The compound Poisson approximations for a portfolio of dependent risks. *Insurance: Mathematics & Economics, 18*, 81-86.

Smid, C.L. (1996). Embedded value en de marktwaarde van verzekeringsverplichtingen. *Het Verzekerings-Archief,73*, 30-35.

Spreeuw, J. (1996). Solidarity in group life insurance. *Blätter der deutschen Gesellschaft für Versicherungsmathematik, XXII*, (4), 817-827.

Vanneste, M., Goovaerts, M.J., Vylder, F. de. & Kaas, R. (1996). A stochastic approach to catastrophic risks. *Scandinavian Actuarial Journal*, 99-108.

Academic publications (excluding publications in/of books) – refereed
1997

Dhaene, J. & Goovaerts, M.J. (1996). Dependency of risks and stop-loss order. *ASTIN Bulletin, 26,* 201-212.

Dhaene, J. & Goovaerts, M.J. (1997). On the dependency of risks in the individual life model, *Insurance: Mathematics & Economics, 19,* 243-254.

Dhaene, J. & Sundt, B. (1997). On error bounds for approximations to aggregate claims distributions. *ASTIN Bulletin, 27*, 243-262.

Goovaerts, M.J. & Schepper, A. De (1997). IBNR reserves under stochastic interest rates. *Insurance: Mathematics & Economics, 21*, 225-244.

Kaas, R., Danneburg, D.R. & Goovaerts, M.J. (1997). Exact credibility for weighted observations. *ASTIN Bulletin, 27*, 287-295.

Schepper, A. de, Goovaerts, M.J. & Kaas, R. (1997). A recursive scheme for perpetuities with random positive interest rates, Part I: Analytical results. *Scandinavian Actuarial Journal, 24*, 1-10.

Vanneste, M., Goovaerts, M.J., Schepper, A. De & Dhaene, J. (1997). A straightforward calculation of the distribution of an annuity certain with stochastic interest rate. *Insurance: Mathematics & Economics, 20*, 35-42.

Vylder, F. de, Goovaerts, M.J. & Marceau, E. (1997). The bi-atomic extremal solution of Schmitter's problem. *Insurance: Mathematics & Economics, 20*, (1), 59-78.

Vylder, F. de & Goovaerts, M.J. (1997). The numerical solution of Schmitter's problem. *Insurance: Mathematics & Economics, 20*, (1), 43-58.

Academic publications (excluding publications in/of books) – refereed
1998

Dhaene, J. & Sundt, B. (1998). On approximating distributions by approximating their De Pril transforms. *Scandinavian Actuarial Journal,* 1-23.

Spreeuw, J. & Goovaerts, M.J. (1998). Prediction of claim numbers based on hazard rates. *Insurance: Mathematics & Economics, 23*, 59-69.

Sundt, B., Dhaene, J. & De Pril, N. (1998). Some results on moments and cumulants. *Scandinavian Actuarial Journal,* 24-40.

Vylder, F. de & Goovaerts, M.J. (1998). Discussion of paper On a class of renewall processes. *North American Actuarial Journal, 2*, 68-70.

Vylder, F. de & Goovaerts, M.J. (1998). Discussion of paper On the time value of ruin. *North American Actuarial Journal, 2*, 72-74.

Vylder, F. de (1998). Discussion of paper Credibility using a loss function from spline theory: parametric model with one-dimensional sufficient statistic. *North American Actuarial Journal, 2*, 111-114.

Wang, S. & Dhaene, J. (1998). Comonotonicity, correlation order and premium principles. *Insurance: Mathematics & Economics, 22*, 235-243.

Academic publications (excluding publications in/of books) – refereed
1999

Dannenburg, D.R., Kaas, R. & Usman, L.N. (1998). Gegeneraliseerde Lineaire Modellen voor IBNR-driehoeken. *Het Verzekerings-Archief, 75*, (4), 149-158.

Denuit, M., Dhaene, J. & Wouwe, M. van (1999). The economics of insurance: a review and some recent developments. *Mitteilungen der schweiz. Aktuarvereinigung 1999, (2),* 137-175.

Dhaene, J. & Denuit, M. (1999). The safest dependence structure among risks. *Insurance: Mathematics & Economics , 25*, (1), 11-22.

Dhaene, J., Willmot, G.E. & Sundt, B. (1999). Recursions for distribution functions and stop-loss premiums. *Scandinavian Actuarial Journal, 1*, 52-65.

Goovaerts, M.J. & Dhaene, J. (1999). Supermodular ordering and the distribution of annuities. *Insurance: Mathematics & Economics, 24*, (3), 281-290.

Goovaerts, M.J. & Redant, R. (1999). On the distribution of IBNR-reserves. *Insurance: Mathematics & Economics, 25*, (1), 1-10.

Goovaerts, M.J. & Dhaene, J. (1999). Supermodular ordering and stochastic annuities. *Insurance: Mathematics & Economics, 24*, (3), 281-290.

Schepper, A. de, Goovaerts, M. & Heijnen, B. (1999). A recursive scheme for perpetuities with positive random positive interest rates. *Scandinavian Actuarial Journal, 1*, 1-14.

Schepper, A. de & Goovaerts, M.J. (1999). The GARCH(1,1)-M model: results for the density and the mean. *Insurance: Mathematics & Economics, 24*, (1-2), 83-94.

Ribas, C., Goovaerts, M.J. & Dhaene, J. (1998). A note on the stop-loss order preserving property of Wang's premium principle. *Mitteilungen, 2*, 237-241.

Vylder, F. de & Goovaerts, M. (1998). Solvency Margins and Equalization Reserves. *Insurance: Mathematics & Economics, 24*, (1-2), 103-115.

Vylder, F. de & Goovaerts, M.J. (1999). Inequality Extensions of Prabhu's Formula in Ruin Theory. *Insurance: Mathematics & Economics , 24*, (3), 249-271.

Vylder, F. de & Goovaerts, M.J. (1999). Explicit Finite Time Ruin Probabilities in the Continuous Case. *Insurance: Mathematics & Economics, 24*, (3), 155-172.

Academic publications (excluding publications in/of books) – refereed
2000

Dhaene J. & Denuit, M. (1999). The safest dependence structure among risks. *Insurance: Mathematics & Economics, 25*, 11-22.

Dhaene, J., Vanneste, M. & Wolthuis, H. (2000). A note on dependencies in multiple life statuses. *Mitteilungen der schweiz. Aktuarvereinigung 2000*, 19-34.

Goovaerts, M.J., Dhaene, J. & Schepper, A. de (2000). Stochastic upper bounds for present value functions. *Journal of Risk and Insurance, 67*, 1-15.

Kaas, R., Dhaene, J. & Goovaerts, M.J. (2000). Upper and lower bounds or sums of random variables. *Insurance: Mathematics & Economics, 27*, 151-168.

Simon, S., Dhaene, J. & Goovaerts, M.J. (2000). An easy computable upper bound for the price of an arithmetic Asian Option. *Insurance: Mathematics & Economics, 26*, 175-183.

Vylder, E. de & Goovaerts, M.J. (2000). Homogeneous risk models with equalized claim amounts. *Insurance: Mathematics & Economics, 26*, 223-238.

Academic publications (in/of books) – refereed
1998

Vylder, F. de (1997). *Life insurance theory: actuarial perspectives.* Boston: Kluwer Academic Publishers.

Academic publications (excluding publications in/of books) - non-refereed
1996

Bogers, J.W.T. (1996). Bifurcations in pension models. *A&E Report, 12/1996*.

Academic publications (excluding publications in/of books) - non-refereed
1997

Goovaerts, M.J. & Dhaene, J. (1997). Actuarial applications of financial models. *CWI Quarterly, 10*, 55-64.

Goovaerts, M.J. Smid, C.L. & Wolthuis, H. (1997). Actuariële leerstoelen, retro- en prospectief. *Het Verzekerings-Archief, 74*, 123-130.

Spreeuw, J. & Wolthuis, H. (1997). Unobserved heterogeneity; process and parameter effects in life insurance. *Tinbergen Institute Discussion Paper, TI 97-131/4.*

Teunen, M. & Goovaerts, M.J. (1997). Stochastic loss reserves based on the separation method. *Giornale dell' Instituto Italiano degli Attuarii, Vol. LVII*, Roma, 9-17.

Academic publications (excluding publications in/of books) - non-refereed
1999

Spreeuw, J. (1999). Heterogeneity of Hazard Rates in Insurance. *AENORM*, *7*, (25), 23-26.

Academic publications (excluding publications in/of books) - non-refereed
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