RECENT RESEARCH DEVELOPMENTS AFFECTING NON-LIFE INSURANCE— THE CAS RISK PREMIUM PROJECT 2012 UPDATE

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ABSTRACT

This paper reports the main results of the 2012 Risk Premium Project (RPP) update, a yearly review of actuarial and finance literature on the theory and empirics of risk assessment for property-casualty insurance. Pricing and modeling insurance risks and methodological advancement in risk valuation were popular fields of research in 2012. Of special note is new work on behavioral pricing and liquidity. Additionally, underwriting cycles attracted some controversy, and emerging risks, such as systemic risk and potential interrelations between insurance and other financial markets were also areas of intense discussion.

BACKGROUND

The aim of the Risk Premium Project (RPP) is to provide a structured summary of the main theoretical and empirical results on risk assessment of property-casualty insurance companies. The project was initiated by the Committee on Theory of Risk (COTOR) of the Casualty Actuarial Society (CAS) in 2000 with a review of actuarial and finance research conducted up to that point in time (RPP I; see Cummins et al., 2000). Due to the vast development of research in both finance and actuarial science, RPP II was conducted to review the research from 2000 to 2010 (see Eling and Schmeiser, 2010). Since then, yearly updates of the literature review have been provided (see Eling, 2013, for the 2011 review). Moreover, a database summarizing all research findings is provided online at www.casact.org/rpp2.

This work reports the results of the 2012 update and summarizes the main findings from publications added to the database. The core elements of the update process included (1) updating the literature collection and (2) writing the update report. The bibliography update involved the addition of newly published work and was conducted from November 2012 to March 2013. The review of the literature was based on the same principles used for RPP II. These principles include the literature search strategy and evaluation of search results (for details on the review process, see Eling and Schmeiser, 2010). Comments from CAS members and other interested parties were received via email or via an online template that was introduced for the first RPP continual update (see www.casact.org/rpp2). Research

papers recommended in this step were incorporated into the database. The RPP II website was updated based on the results of the literature review.

This paper summarizes the most important developments from the literature update, with a focus on research published in academic journals in the fields of actuarial science, risk management, and insurance. Related fields were also considered, especially articles published in the finance literature. Moreover, new working papers such as those suggested by CAS members are integrated into the review. In total, 95 new papers were considered in the review process.

In the following section we present the main results of the continual update. Conclusions and a brief outlook are given in the final section.

RESULTS

Table 1 provides an overview of the thematic categories that were developed for RPP II and the number of papers that were added during the 2012 continual update process. The three top-level categories are based on the classic risk management process: risk identification, followed by risk valuation, and ending with the application of appropriate measures to address the identified risk exposure (risk management). Each of the top-level thematic categories is subdivided into several subcategories. There has been some discussion as to whether new subcategories need to be added to the RPP review framework, such as regulation or systemic risk. These aspects could form a separate category, but they also can be fit into existing categories. Work on systemic risk can be found in the category "Other Emerging Risks" and work on regulation is under "New Valuation Techniques". The existing structure thus still concisely covers all relevant aspects of risk assessment in property-casualty insurance.

Table1 Thematic categories and number of papers added during the 2012 update

Thematic category	Number of new publications
Panel A: Risk Identification	15
Operational Risk	3
Catastrophe Risk	5
Other Emerging Risks (e.g., Systemic Risk)	7
Panel B: Risk Valuation	62
CAPM/Asset Pricing	12
Insurance Risk	25
New Valuation Techniques (e.g., Solvency II, MCEV)	9
New Risk Measures (e.g., Tail Value at Risk)	12
Behavioral Insurance	4
Panel C: Risk Management	18
Surplus/Capital Allocation	6
Risk Control (e.g., Risk Mitigation)	2
Reinsurance and Alternative Risk Transfer	10
Total	**95**

Within the *Risk Identification* category special emphasis is put on research into operational, catastrophe, and other emerging risks. Papers covering aspects of operational risk are allocated to the subcategory "Operational Risk". Work on catastrophic risks is collected in the subcategory "Catastrophe Risk"; other emerging risks that are of a non-catastrophic nature are captured in "Other Emerging Risks". The classification of papers in a specific subcategory is certainly not exclusive as papers covering several elements of the risk management process may qualify for more than one category.

Within the *Risk Valuation* category, the focus is on three new aspects. First, new valuation techniques, including valuation of insurance risks based on market consistent embedded value (MCEV), Solvency II, International Financial Reporting Standards (IFRS), and others. Second, new risk measures, such as value at risk, tail value at risk, and spectral risk measures, and their role in insurance pricing. And third, aspects of behavioral insurance aimed at explaining why observed market behavior deviates from that predicted by neoclassical theory.

The *Risk Management* category includes recent developments in the fields of capital allocation, risk control, and risk engineering in reinsurance and alternative risk transfer. The increasing use of new valuation techniques increases the importance of risk mitigation and risk-sharing instruments, which in turn call for a focus on the relationships between the price of insurance, the price of reinsurance, and the price of risk mitigation. Risk transfer and risk mitigation, for example, can be considered as substitutes. Moreover, alternative risk transfer instruments can be used to derive insurance prices, e.g., by considering prices of cat bonds.

More details on the search process and the thematic categories can be found on the RPP II webpage (see CAS, 2013). In total, 95 new papers were added during the 2012 update, with the risk valuation category receiving the most (62 new papers), followed by the risk management category (18 new papers) and the risk identification category (15 new papers). The distribution of the literature added reflects the distribution of papers in the existing RPP II database, with the risk valuation category containing 561 papers, risk management 187 papers, and risk identification 232 papers.

In the following we discuss the central results for each category. Note that although we try to be as objective as possible when selecting the most notable publications, relying to a large degree on recommendations from colleagues, a certain amount of subjectivity is unavoidable. Recommendations for additions to the list are welcome and can be made at http://www.casact.org/research/rpp2.

Risk Identification

Operational Risk: Operational risk is a relatively new field of research that analyzes the risk of losses resulting from inadequate or failed internal processes, be these human or otherwise (see BIS, 2001). Three papers were added to the database in this category. Plunus, Hübner,

and Peters (2012) rely on a modified credit risk model that they adapt to the operational risk case to estimate the value at risk. Their model is especially appropriate for small samples and is thus valuable for fitting operational loss distributions, an advantage the authors illustrate with simulated and empirical loss data. Cerchiello and Giudici (2012) apply a fuzzy-logic approach in the operational risk context and propose a method for "fuzzifying" qualitative variables that they apply to a corporate database. In contrast to traditional models that transform qualitative variables into binary ones (e.g., dummy variables), their model performs a more accurate predictive regression analysis by avoiding the typical loss of information suffered by traditional models. The work by Carrillo-Menéndez and Suárez (2012) focuses on a robust quantification of operational risk.

Catastrophe Risk: Work in the field of catastrophe risk is a "hot" topic these days, especially in light of increasingly frequentnatural disasters and the often reported failure to insure against these risks. New work added to the field of catastrophic risk (five papers) is concerned with explaining market failures, suggesting viable catastrophe insurance schemes, calculating premiums for catastrophe insurance, and investigating the role of catastrophic risk in property-casualty insurance insolvencies. Kousky and Cooke (2012) aim at explaining the decision not to buy catastrophe insurance when fat tails, microcorrelations, and tail dependence are present. They infer that catastrophic loss characteristics require insurers to hold enormous levels of equity capital that drive up premiums to such a level that it is not rational for individuals to purchase catastrophe insurance policies. Their results indicate that in addition to the behavioral biases and information search costs often offered in explanation for the low demand for catastrophe insurance, the high costs of premiums caused by catastrophe risk characteristics are another important factor in this market. Cheng and Weiss (2012) analyze property–liability insuranceinsolvencies during the period of 1994 to 2008and find a significant impact of hurricane risk exposure for the U.S. market. Through the identification of hurricane exposure as a new variable that explains insolvencies and the unreliability of usually applied risk-based capital ratios, this study reveals the need to revise existing solvency surveillance systems, with catastrophe risk exposure playing a potentially important role in such revisions. A methodological contribution to the literature is provided by Nowak and Romaniuk (2013).They begin with the proposition that traditional insurance mechanisms are inadequate to deal with catastrophic risks due to extant dependencies and focus on different forms of catastrophebonds for which they develop pricing models. Their work is an important extension of commonly used pricing models and providesa general pricing formula for catastrophe bonds.

Other Emerging Risk: The subcategory "Other Emerging Risk" had seven new papers added to it in the 2012 RPP update. The new work focuses on increasing climate, environmental, and systemic risk, the latter of which receives particular attention in three new publications. One of these is Billio et al. (2012), which focuses on measurement of systemic risk in the finance and insurance sectors. The authors suggest several econometric measures of connectedness based on principal-components analysis and Granger-causality networks.

Their application to monthly returns of hedge funds, banks, broker/dealers, and insurance companies shows that all four sectors likely have seen increasing levels of systemic risk over the past decade due to high interrelationsand complex and time-varying relationships. The analysis includes property-casualty insurers and is as such interesting since, up to this point, only life insurers have been considered to exhibit systemic risk exposure. Boyle and Kim (2012) also suggest a new risk measure to capture systemic risk and then go on to propose a countercyclical insurance program design for systemic risk that avoids the usually found pro-cyclicality of capital requirements through a countercyclical risk charge.

Thomann, Pascalau, and Schulenburg (2012) analyze management decisions about terrorism insurance made by corporate risk managers in Germany. A central finding from this study is that firms learn from single-loss events and use this knowledge in subsequent risk management decisions with increasing confidence. Specifically, the authors' results show a general tendency toward policy cancellation, but an upswing in the purchase of terrorism insurance contracts by previously uninsured companies subsequent to new terrorist events. In general, financial corporations, large corporations, and corporations based in larger cities are prone to buy terrorism insurance.

In a study on climate change, Kapphan, Calanca, and Holzkaemper (2012) analyze the hedging effectiveness and profitability of weather insurance designs based on historical data. They demonstrate that weather insurance requires regular updating (e.g., strike level, size, and cap) in times of climate change in order to effectively hedge future weather risk and avoid substantial losses. Depending on the index and the climatic conditions, the authors find that the insured is either over- or under-compensated if the insurer fails to update the coverage for changes induced by climate change.

Risk Valuation

CAPM/Asset Pricing: Twelve papers on asset pricing were added to the database in the current RPP update cycle. Most of the publications focus on classic portfolio-selection problems and extend previous models. Chiu and Wong (2013) are concerned with the optimal investment behavior of insurers when co-integrated assets are present and insurers are subject to random claims payments. The availability of co-integrated risky assets implies the potential presence of arbitrage opportunities. In light of insurers' role of managing pure risk and offering protection, the authors are interested in whether those arbitrage opportunities provide social benefit to insurers. They find that riskier insurers are likely to participate in arbitrage opportunities, whereas more risk-averse ones are not.They conclude that insurers need to be well regulated to ensure their social responsibility.

A related area of research concerns methodological advancement that promotes, for example, fuzzy logic for portfolio selection and performance measurement. Kamdem, Moussa, and Terraza (2012) develop new performance measures based on fuzzy logic, which they apply to evaluate hedge funds. They show how their new fuzzy risk-adjusted versions of the Sharpe

ratio, the Treynor ratio, Jensen's alpha, and the information ratio efficiently deal with the closing-based returns bias induced by market microstructure noise and handle stochastic variability of returns. The fuzzy risk-adjusted performance measures are estimated and compared with their traditional counterparts for a dataset of 50 French hedge funds.

Insurance Risk: As was the case for the 2011 RPP continual update, the "Insurance Risk" subcategory once again had the most additions in 2012—25 papers. A central focus of these papers is on modeling insurance risk andenhanced pricing capabilities. One interesting new idea is the use of behavioral approaches for pricing insurance risk. Kaluszka and Krzeszowiec (2012) rely on cumulative prospect theory to introduce anew premium principle. The basis for this approach is the Tversky and Kahneman (1992) model of a rank-dependent utility model in which individuals are assumed toexhibit a four-fold pattern of risk attitudes, i.e., with high loss probabilities, risk aversion for gains and risk seeking for losses is expected, whereas for low loss probabilities, risk seeking for gains and risk aversion for losses is expected. The authors thus extend earlier results by Heilpern (2003) and Goovaerts, Kaas, and Laeven (2010) and show that their new approach satisfies the most important properties of premium principles, such as translation and scale invariance and additivity.

A particularly important new work is that of Ma and Ren (2012), which was recommended via the RPP online template. The authors contribute to the understanding of linkages between stock and insurance markets by measuring the sensitivity of both premiumgrowth and relative executiveequity compensation to stock prices over the period from 2004 to 2008 and identifying a novel interaction between those variables. Specifically, they find evidence that higher premium growth is generated by publicly traded property-casualty insurers in phases when the stock market is more sensitive to growth performance. The identified relationship is more prevalent for firms with higher relative executive equity compensation. Their results have important implications in that publicly traded insurers' tendency to cater to the stock market may distort insurance production and pricing; those interactions thus require regulatory attention.

Liquidity risk is the focus of a project funded by the CAS (see CAS, 2011). The aim of the project is to study the effect of illiquidity on pricing and valuation of financial assets and liabilities. In a broader sense, liquidity describes the ability to trade a good or service at a unique price at any given time, which is a central aspect of an efficient market. In the absence of these conditions, an illiquid market exists. For the most part, property-liability insurance markets are more characterized by illiquidity than by liquidity, with buyers of individual insurance being price takers and buyers of commercial insurance being either price takers or price makers depending on the insurance market capitalization. The authors of the study deal with the impact of illiquidity by developing an extension of the one-price economy – the two-price economy. In particular, they analyze implications of their theory for optimal reinsurance and hedging strategies.

Insurance cycles were another area of research interest in 2012. Lazar and Denuit (2012) provide new evidence for the existence and length of underwriting cycles in the U.S. property-liability insurance industry. They specifically test two new approaches for insurance cycles and find empirical evidence for a cyclical behavior of property-liability real premium growth rates ranging from five (traditional approaches) to eight years (new approaches). Opposed to the prevailing finding of persisting insurance cycles in property-liability insurance markets, Boyer, Jacquier, and Norden (2012) conclude that any evidence of underwriting cycles could actually be spurious. On the basis of U.S. data from 1967 to 2004, they show that parameters found for autoregressive models in previous studies are strongly biased in favor of finding cyclicality and are thus misleading. Correcting for this bias and carefully checking for in-sample and out-of-sample predictability, they no longer find evidence of insurance cyclesor insurance cycle predictability.

Another study in the area of insurance risk focuses on how foreign ownership influences insurer efficiency. Using data envelopment analysis, Huang, Ma, and Pope (2012) find that foreign ownership has a positive impact on insurer efficiency for the Japanese property-casualty insurance market in the time period 1992 to 2005. Their results also suggest an increase in the observed disparity between foreign-owned and domestic institutions.

New Valuation Techniques: Nine publications were added to the category of new valuation techniques, with a leaning toward market-consistent valuation. Gatzert and Martin (2012) consider the current Solvency II framework and critically discuss the absence of risk-capital requirements for the credit risk inherent in government bonds in light of the European sovereign debt crisis. They develop an alternative partial internal risk model that explicitly includes credit risk and find that the Solvency II standard model underestimates (overestimates) the risk of low-rated (high-rated) bonds.

Various advances in modeling property-casualty insurance risk have been made, including the modeling of tails, skewed distributions, and dependence structures. Due to the wide variety of models available in the field of property-casualty insurance, selecting "appropriate" models is crucial. Ahčan (2012) analyzes model risk and its impact on pricing weather derivatives within the scope of a modeling approach and an empirical application. By comparing different statistical models for weather indices, the authors find that popular normal models donot adequately capture tail risk and consequently lead to mispriced out-of-the-money options.

Heavy tailed distributions are addressed in more depth in Ahn, Kim, and Ramaswami (2012). They study the properties of a class of log phase-type distributions, including their tail-related characteristics, for fitting heavy-tailed loss data. A central advantage of log phase-type distributions over other approaches, such as extreme value theory, is the avoidance of a complex prior tail threshold determination by directly fitting the data as a whole. Thus, the log phase-type distributions are viewed as a qualified class of heavy-tailed distributions that render unnecessary the separate modeling of the tail side.

Another relevant area of research is modeling dependence structures of property-casualty insurance claims. Diers, Eling, and Marek (2012) analyze the properties of the Bernstein copula in comparison to other widely used copulas by fitting German storm, flood, and water claims data. Their results highlight the applicability of the Bernstein copula in internal risk models and its particular advantage when dependence structuresare inhomogeneous, not extremely highly correlated, and when data are sparse; these conditions are frequently found in property-casualty insurance companies.

New Risk Measures: Twelve new articles on risk measurement were added to the database. As was the case in 2011, most of these are concerned with quantile-based risk measures, such as the tail value at risk or conditional tail expectation. The focus of the 2012 publications, however, is on applying such measures in the property-casualty insurance industry: to capital allocation (see Cossette, Mailhot, and Marceau, 2012), optimal reinsurance (see Lu, Liu, and Meng, 2013), and risk-transfer (see Guerra and Centeno, 2012). The authors of the latter work take a critical stance on the suitability of quantile-based risk measures (value at risk, conditional tail expectation) as optimization targets when deciding about risk-transfer in an insurance firm. They show that the resulting decisions can be infeasible or even have a detrimental effect on the ceding insurer's risk situation. Specifically, the authors find solutionswhere optimal reinsurance contractsfor the ceding primary insurer provide protection against moderate losses and almost no protection against large losses. The results highlight the inadequacy of these strategies since small losses could be borne by the primary insurer's equity, whereas reinsurance becomes crucial when losses are large.

Behavioral Insurance: Behavioral insurance is a relatively new field of research that is rooted in behavioral economics and behavioral finance. A central paradigm in this field is that psychological components such as social, cognitive, and emotional factors play a role in human economic decision making. The new literature in the "Behavioral Insurance" subcategory (four papers) broadens the novel field of behavioral insurance by addressing new markets such as flood insurance (see Browne, Knoller, and Richter, 2012) and microinsurance (see Kunreuther and Michel-Kerjan, 2012; Landmann, Vollan, and Frölich, 2012). The work by Kunreuther and Michel-Kerjan (2012) is particularly interesting as it analyzes how developing countries can improve their disaster preparedness by taking into account behavioral biases and simplified heuristics of the key decision makers. As potential strategies for addressing these issues, the authors stress the role of multi-year microinsurance, long-term loans, and multi-year catastrophebonds to align short- and long-term incentives. Landmann, Vollan, and Frölich (2012) test the impact of the availability of microinsurance products on solidarity in rural risk-sharing groups in an experimental laboratory setting in the Philippines. One central finding of their work is the persistence of crowding-out of solidarity induced by market-based insurance mechanisms, which continues to exist even when insurance is removed again.

Risk Management

Capital Allocation: The field of capital allocation garnered five new publications in the 2012 RPP update, several of which are linked to other subcategories, such as "Catastrophe Risk" and "New Risk Measures". One interesting paper not previously discussed is that by Das and Kratz (2012), who develop a novel strategy for more efficient use of scarce equity capital resources while controlling for ruin probability in an insurance firm. They argue that high initial levels of equity capital are not desired by most companies and alsonot feasible in certain situations. As a potential solution, the authors suggest an alarm system that allows for less initial capital and includes facilities to increase capital levels when needed. Numerical and analytical validation procedures show thata dynamic approach based on an alarm system exhibits a higher finite long-run survival probability compared to a similar system without an alarm feature. Xu and Hu (2012) are concerned with how different capital allocation strategies affect the general loss function in a stochastic framework and how different assumptions influence the dependence structure of insurance risk. Their theoretical results are then applied to optimal capital allocation and policy limits allocation problems. Cossette, Mailhot, and Marceau (2012) focus on a tail value at risk-based multivariate capital allocation problem from a top-down perspective. They derive closed-form expressions for the aggregate claim amount and its respective risk measure in the multivariate compound distributions case with gamma and mixed Erlang claim amounts.

Risk Control: Two papers were added to the "Risk Control"subcategory, one of which is concerned with corporate diversification (see Berry-Stölzle et al., 2012) and the other with asset-liability management (Yao, Lai, and Li, 2013). An interesting result with regard to the two fundamental forms of organization in insurance markets—mutual firms or stock firms—is presented in Berry-Stölzle et al. (2012). The authors first find empirical support for the managerial discretion hypothesis, predicting that mutual insurers areless diversified than stock insurers. A key reason for the prior inability to detect evidence of the diversification prediction from the managerial discretion hypothesis is the use of relatively broad "total diversification" measures. In addressing this issue, the authors define a measure of "unrelated line-of-business diversification;" i.e., diversification in dissimilar lines of business. Although their specific measure of diversification supports the managerial discretion hypothesis, the total diversification measure does not, a common finding in the literature.

Reinsurance and ART: Reinsurance and alternative risk transfer (ART) has been a fruitful field of research in 2012, amassing 10 new publications. Whereas in 2011, the largest share of new publications was in the area of ART, the 2012 publications are mostly concerned with identifying optimal reinsurance strategies under various constraints. An example is Cai and Wei (2012), which is an analysis of optimal reinsurance purchase when risks are positively dependent. Under the individual risk model assuming positive dependence between risks, the authors find that excess-of-loss policies are the dominant option to minimize certain risk measures of retained losses.

On the alternative risk transfer side, Villegas, Medaglia, and Zuluaga (2012) focus on the pricing of various ART solutions, including multi-trigger products and insurance-linked securities. As an alternative to complex and customized derivative and actuarial pricing strategies involving strong assumptions about the distribution of important risk factors, the authors suggest the use of optimization-based methods computing upper and lower price bounds that rely on market data and expert information.Their approach is especially advantageous in situations where data on risk factors are scarce and the product's structure is too complex to derive analytical solutions.

CONCLUSION AND OUTLOOK

Based on the review results, as well as on feedback from the academic and practitioner communities, it appears that the pricing and modeling of insurance risks and advances in the valuation of insurance risk are important research topics in property-casualty insurance at the moment. This is particularly true when it comes to discussion of new valuation techniques for and controversies regarding the Solvency II risk-based capital requirements and for the application of new risk measures in fields such as capital allocation and optimal reinsurance. New and interesting work on behavioral pricing and liquidity has been added to the literature. Moreover, the relevance of systemic risk and underwriting cycles is critically discussed in recent literature.

In light of the persistent European sovereign debt crisis and low economic growth in major Western economies, we should expect more research on the consequences of such for the insurance industry and discussion revolving around international growth and diversification strategies. Rising economies, especially in the developing world, have been on the agenda for some time, but may become even more relevant in the future. For example, the *Geneva Papers on Risk and Insurance* is planning a special issue on microinsurance for 2013. Moving insurance resources to new markets may also have an impact on prices and availability of insurance coverage in insurers' home markets such that resources may be shifted to new markets after good years when the industry is sufficiently capitalized with potential effects on premiums and cyclicality of underwriting. In this context, the revelation by Boyer, Jacquier, and Norden (2012) that any evidence of underwriting cycles found so far in the literature could be spurious is interesting and may inspire further work on that issue for a larger set of countries.

High catastrophic losses over the last years have increased the significance of the catastrophic risk category. Insurers need to improve their models to better capture dynamic changes in climatic risk, develop new products that cover risks effectively and are economically viable, and create new facilities to transfer and diversify risk exposure. The massive changes in the insurance market environment due to expected future catastrophes also call for effective risk mitigation strategies. This field of research has received relatively little attention to date, but will be crucial to sustain economic development.

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