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EDITORIAL

Keng Seng Tan 1970–2023 In Memoriam

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The editorial is dedicated to the memory of Ken Seng Tan, who passed away on January 1, 2023, at the height of his academic career. He was one of the most influential and prolific actuarial researchers of the last three decades.

Ken Seng Tan moved to Canada from Malaysia for his undergraduate studies and remained there until 2019. In 1998, he completed his PhD in Actuarial Science at the University of Waterloo, where his doctoral thesis, *Quasi-Monte Carlo Methods: Applications in Finance and Actuarial Science*, won a university award for Outstanding Achievement In Graduate Studies.

Ken Seng became an Assistant Professor in the Department of Statistics and Actuarial Science at the University of Waterloo in 1998. He held a Canada Research Council Chair in Quantitative Risk Management from 2005 to 2010 and a University Research Chair from 2010 to 2015. From 2006 to 2015, he was Associate Director of the Institute for Quantitative Finance and Insurance and its successor, WatRISQ. Ken Seng also held a long-term visiting position at the Central University of Finance and Economics in Beijing, where he was active in supporting Chinese actuarial education and research. In 2019, Ken Seng joined Nanyang Technical University in Singapore, where he held the President's Chair in Actuarial Risk Management, and was Director of the Insurance Risk and Finance Research Centre.

Ken Seng Tan was a brilliant actuary, researcher, educator, mentor, and academic leader. He published over 140 research papers and book chapters on topics in actuarial science, insurance, finance, and risk management. He was active on the editorial boards of several major journals, including the Annals of Actuarial Science. He was awarded both the Hachemeister and the Redington Prizes by the Society of Actuaries (SOA), who also named him as one of 24 inaugural Chartered Enterprise Risk Analysts for his thought leadership and pioneering achievements in the field. In this editorial, we hope to provide a sense of the breadth and depth of his academic contributions and also to celebrate his life using the words of some of his co-authors.

We focus on four main areas of Ken Seng's research; computational finance, longevity risk management, optimal (re)insurance, and agricultural insurance. In each part, we cite some of his most influential papers, but we note that this is a small sample of his work.

Computational Finance

In his doctoral research, Ken Seng and his supervisor, Phelim Boyle, studied the application of quasi-Monte Carlo (QMC) simulation in computational finance. Many quantitative problems in

[†]The authors are grateful to the following people for their contributions to this editorial: Chengguo Weng, Wenjun Zhu, Lysa Porth, Adam Kolkiewicz, Johnny Siu-Hang Li, Sheng Chao Zhuang and Junichi Imai.

finance and actuarial science can be reduced to the computation of expectations or the integration of a function. At that time financial practitioners used regular Monte Carlo simulation to evaluate complex integrals associated with exotic derivative contracts. QMC works similarly, except that there is no attempt to sample randomly (or even pseudo-randomly). Instead, the method uses a systematic sampling approach based on low-discrepancy sequences from number theory. It offered much faster convergence of numerical integrals than regular Monte Carlo simulation, making it very promising for the financial engineers, who were looking for computational efficiency. Ken Seng explored the application of QMC to financial pricing, analysed advantages and disadvantages of different sequences, developed a method for randomising the QMC sequences to overcome problems arising for high dimension problems, and identified criteria for assessing when QMC or lattice algorithms would offer better outcomes. This work is summarised in Joy *et al*. (1996) and Tan & Boyle (2000).

Subsequently, with his typical energy and optimism, Ken Seng engaged several collaborators, notably Adam Kolkiewicz and Junichi Imai, to pursue different ideas related to the development of these new pricing methods. There are three major challenges in applying low-discrepancy sequences to high-dimensional integration problems. First, typically they require an efficient inverse simulation method to reach full superiority over standard Monte Carlo. Secondly, the sequences provide inadequate coverage of the probability space in high dimensions. Thirdly, the method may fail if there are any discontinuities in the integrand. In his work, Ken Seng looked at each issue and proposed several innovative solutions. One method of addressing the first challenge was formulated in a series of papers that Ken Seng wrote with Phelim Boyle and Adam Kolkiewicz, where the authors presented a novel quasi-Monte Carlo approach to pricing high-dimensional American options (e.g. Boyle *et al*., 2003 and Boyle *et al*., 2013). Another technique that can be used in situations when the inverse method is not readily available was presented by Ken Seng in a joint paper with Junichi Imai (Imai & Tan, 2009), where the authors considered the problem of pricing for a class of Levy processes. The problem of identifying the true dimensionality of an integrand, and of developing methods to reduce the dimension, was the subject of several papers, including in joint work with Junichi Imai (Imai & Tan, 2014) and with Xiaoqun Wang (Wang & Tan, 2012). Finally, in another paper with Xiaoqun Wang (Wang & Tan, 2013), Ken Seng formulated a clever method for dealing with a discontinuous integrand. These are just a sample of the extensive array of contributions made by Ken Seng and his collaborators in the area of efficient pricing of complex derivative contracts.

Longevity

Ken Seng began his collaboration with Johnny Siu-Hang Li, working on longevity modelling and risk management, in 2005, just before the topic erupted as a major area of risk and of research. Together with several co-authors, their work resulted in a series of papers on topics including uncertainty measures in longevity models, multi-population modelling, and the financial economics of mortality-linked securities.

A notable publication from this collaboration was Li *et al*. (2009), which extends the Lee-Carter model to allow for heterogeneity within each age/year cell, hence providing more realistic confidence bounds for longevity projection. Another is Li *et al*. (2010), which combines financial pricing and longevity models in an early analysis of the financial economics of reverse mortgage contracts.

The team moved on to multi-population models, with a particular focus on mortality-linked securities. They were joined by Rui Zhou in much of this work. In Zhou *et al*. (2011), they consider the impact of basis risk (the difference between the longevity costs incurred by a longevity hedger and the longevity insurance provided) on pricing and on the supply/demand relationship of mortality-linked securities, as well as suggesting ways to construct a static longevity hedge. In Zhou *et al*. (2013), they develop a multi-population mortality model incorporating transitory

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jumps (e.g. from pandemics) and use it to investigate the impact of jumps on supply and demand of mortality-linked securities.

In one of his most recent papers, Tan *et al.* (2022), Ken Seng continued his work on mortality-linked securities and basis risk, applying earlier work on mean-variance hedging to propose a dynamic longevity hedge strategy for a stylised pension plan.

Optimal Insurance

Another very fruitful collaboration that began in the mid-2000s was with Chengguo Weng. Their work pioneered the study of optimal reinsurance under the minimisation of popular risk measures, including VaR and CTE, incorporating desirable constraints (e.g. premium budget and profitability), and considering optimal forms of reinsurance from a set of general indemnification functions (Cai *et al.*, 2008; Tan & Weng, 2012).

While optimal insurance research is typically quite abstract, Ken Seng adapted the theory to provide practical real-world insights and results. With Chengguo Weng and Sheng Chao Zhuang, and others, he investigated optimal insurance in a range of more practical settings, expanding the context to multiple periods, or multiple perspectives. In Boonen *et al.* (2016), for example, he and his co-authors explored a model with multiple reinsurers and one insurer, showing that for very general insurer preferences, there exists an intuitive distortion pricing formula for all reinsurers. In Zhuang *et al.* (2017), they considered optimal insurance simultaneously from the perspectives of the insured, the insurer, and the reinsurer. By assuming that the preferences of the parties are given by distortion risk measures, they showed that the optimal insurance and reinsurance is of the form of layering, with each party bearing a layer of risk. Their work also demonstrated that adequate reinsurance capacity can alleviate the problem of under-insurance.

In Zhang *et al.* (2019), Ken Seng and his co-authors derived an optimal index insurance design under a general utility maximisation setting. Under index insurance, the payoff in the event of a claim is related to a pre-specified metric or index, rather than the actual loss. Index insurance has many advantages over loss-based insurance, for example in simplifying claims management and reducing moral hazard. The major challenge is basis risk – that is, the difference for individual policyholders between the loss incurred and the claim paid. Ken Seng had become interested in index insurance because of its potential value to increase insurance capacity in developing countries, particularly for small-scale agricultural operations. The optimal design developed in Zhang *et al.* (2019) was shown to reduce basis risk significantly compared with the traditional linear payoff.

Agricultural Insurance

Ken Seng started working on agricultural insurance around 2011, together with Lysa Porth and Wenjun Zhu. The actuarial science of agricultural insurance was an under-researched area when the team started working together, and their collaboration produced a number of important research results. Agriculture is often recognised as the world's largest industry with major social and economic significance. The industry is highly sensitive to weather-related risks, which are becoming increasingly unpredictable as a result of climate change. The problem that Ken Seng and his colleagues were concerned with was that the growing demand for agricultural insurance was not matched by supply, as climate change uncertainty and the complexity involved in modelling spatially dependent losses contributed to a lack of insurance capacity.

Under Ken Seng's leadership, the team conducted some of the first studies that applied predictive analytics to agricultural insurance pricing, climate risk management, and sustainability. For example, in Porth *et al.* (2013), Ken Seng brought his knowledge of optimal insurance theory to the team's analysis of crop insurance design, and in Porth *et al.* (2014), they used an Erlang mixture distribution in a credibility-weighted scheme to combine local and national crop loss data. The resulting reinsurance premium offers a more scientific pricing methodology than standard

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methods. In Zhu *et al.* (2019), the team proposed new premium principles to help establish actuarial best practices for pricing of agricultural insurance. Advanced weather risk models were used to better understand the dependency of risks, for example in Zhu *et al.* (2018) and Li *et al.* (2021). The research team also expanded their work regarding predictive crop yield models for index-based insurance applications, including the use of satellite remote sensing for forage insurance, which included important collaborations with government, insurers, reinsurers, and technology providers (Porth *et al.*, 2020).

Concluding Comments

In reviewing Ken Seng's contributions to actuarial science and risk management, we are struck by several themes. The first is the sheer range of his interests. He was an actuarial polymath. In each area that we reviewed, he co-authored papers that have proved highly influential, winning prizes, and garnering high citation counts. In moving between these areas, he created connections that enriched the research of each. His work on computational finance informed the numerical methods that he used in his optimal insurance and longevity research. Basis risk was a common feature of his research in mortality securitisation, index insurance, and agricultural insurance, and his early work on mean-variance hedging provided a foundation for analysing and mitigating basis risk in each context. Many of his most recent papers continue to develop and apply theory and methods from his earlier work in new contexts.

He also always wanted his research to be useful. His co-authors highlighted his emphasis on developing practical numerical methods to apply and test theoretical results. His papers consistently combine strong technical theory with real-world practicality. Some work is more abstract, some more applied, but as a body of work it offers strong support for the adage that 'there is nothing so practical as a good theory'.

Ken Seng's drive to use his research and his position to make a difference in the world increased in recent years. In 2015, he took on a leadership role in a major project developing actuarial education and research in Indonesia, known as the READI Project[1]. Through insights gained from travelling around the country, and through extensive discussions with actuaries and regulators, Ken Seng became highly motivated to conduct research into how insurance could be used to support small-scale agriculture operations in developing countries. This along with a growing awareness of the problems of climate change and food security motivated much of his most recent work on agricultural insurance. It is worth noting that when he started working on agricultural insurance, it was not at all a popular topic, and Ken Seng knew that the work might not garner the citations that would come from working on something more fashionable. This did not daunt him. He could see the potential to be useful and that was more important to him than traditional academic metrics.

More recently, moved by the successes and failures of insurance, reinsurance, and securitisation in managing the costs of the COVID-19 pandemic, Ken Seng initiated a major project exploring the potential for public-private provision of pandemic-related reinsurance.

Many of his co-authors commented on how ambitious and fearless Ken Seng was in his research, and this carried over into his wider academic activities. Recognising the need to bridge the gap in agricultural insurance research between stakeholders from academia, government, private sector, and NGOs, he and Lysa Porth established the *International Agricultural Risk, Finance, and Insurance Conference* (IARFIC). From the inaugural event held in 2012 in Beijing, China, IARFIC gained momentum, and in the following six years, Ken Seng and Lysa arranged IARFIC meetings in Canada, Switzerland, the USA, and France.

Ken Seng also applied his immense energy and ambitious outlook as champion of the READI project, a massive multi-million dollar undertaking. This involved him in extensive work within

[1]The Risk Management, Economic Sustainability, and Actuarial Science Development in Indonesia (READI) project ran from 2015 to 2021. See https://uwaterloo.ca/risk-management-economic-sustainability-actuarial-science-development-indonesia/.

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Indonesia, connecting with insurers and regulators, encouraging universities and individual faculty members to participate, developing research grant programmes, and supporting individual researchers and teachers. His work changed the face of insurance and academic actuarial science in Indonesia.

Ken Seng enjoyed the process of collaborative research, the synergies, the breakthroughs, and the friendships crafted through joint endeavours. He was the most generous colleague and an extraordinary mentor. It is not surprising that people who worked with Ken Seng wanted to continue working with him, and it is notable how enduring those collaborations were. His first paper with Phelim Boyle was published in 1996; his latest is Boyle *et al*. (2022). His first paper with Adam Kolkiewicz was published in 2003; his latest is Puspita *et al*. (2020). His collaboration with Lysa Porth began in 2011; their most recent joint work is Li *et al*. (2021).

The following comments contributed by some of his co-authors give a sense of how valued he was as a collaborator and friend.

> *Ken Seng was renowned for his big research ideas, creativity, and impactful solutions, emanating an intense passion. He had a contagious sense of humour, was a mentor to many, and a friend to all. Those who had the privilege of working with him couldn't help but share his excitement in developing new approaches and forging new partnerships, and he had a special ability to unite researchers from academia, industry, and government.*
> Lysa Porth and Wenjun Zhu

> *Working with Ken Seng was easy, enjoyable, and very rewarding. He was not only a constant source of new ideas, but when confronted with obstacles he never gave up easily. The scope of his research interest was enormous, and still growing. There was no new problem in finance or insurance which he would not consider as a potential topic for research. He enjoyed working with others and always generously shared his research enthusiasm and experience with his colleagues.*
> Adam Kolkiewicz

> *His broad perspective and deep insight into financial engineering and actuarial science have greatly expanded the potential for practical applications. His research style was based on a solid mathematical background, but he could also take a bird's eye view and unconventional approach from a different perspective.*

> *Our collaboration began in 1999. From that time, he has been incredibly generous and supportive of my personal life and research career. His personality made it possible for our collaboration to continue for so long.*
> Junichi Imai

> *There are certainly reasons why Ken Seng is so popular as a research supervisor. He is generous, thoughtful, and always does his very best to help his students with their academic careers. He is also open-minded, letting his students explore different non-traditional, but timely, actuarial research topics including carbon financing and climate change risk. Ken Seng's dedicated mentorship has provided the foundation for fruitful research careers for very many students and colleagues.*
> Johnny Siu-Hang Li

Ken Seng Tan was a highly talented researcher. He was also the most compassionate, generous, and gracious person, with a unique capacity to form lasting friendships with people from all walks of life throughout the world. He was an inspiring mentor and role model to hundreds of students and colleagues. Through his work and through the work of his students, colleagues, and friends, he has left us a lasting legacy.

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