

Brave New Risks: Tracing the evolution of actuarial research from the *Accounting & Finance Review* to the frontiers of Actuarial Science

João Vinícius de França Carvalho¹

 <https://orcid.org/0000-0002-1076-662X>

Email: jvfcarvalho@usp.br

¹ Universidade de São Paulo, Faculdade de Economia, Administração, Contabilidade e Atuária, Departamento de Contabilidade e Atuária, São Paulo, SP, Brazil

Received on 11/14/2025 – Desk acceptance on 11/21/2025 – 2nd version approved on 12/12/2025

Academic Editor-in-Chief: Andson Braga de Aguiar

Guest Editors: Márcia Martins Mendes De Luca, José Alonso Borba, Raquel Wille Sarquis and Daniel Magalhães Mucci

ABSTRACT

This article aimed to examine the thematic evolution and methodological trajectory of research on Actuarial Science in the *Accounting & Finance Review* (A&FR), to assess its main intellectual contributions, and to shed light on promising avenues for future research. Despite its relevance, research on Actuarial Science in Brazil has remained fragmented, with limited integration between traditional pension studies and emerging domains such as insurance analytics, climate finance, and risk management. No prior study in Brazil has systematically mapped these developments or articulated a unified research agenda linking Actuarial Science to Finance, Accounting, and Sustainability. By documenting the A&FR's historical contribution and outlining future directions, this study advances the understanding of how research on Actuarial Science can address new societal and regulatory challenges. It shows the discipline's potential to strengthen public policy, enhance financial resilience, and support evidence-based regulation. This article positions the A&FR as a key platform for publishing papers on Actuarial Science in Latin America and proposes a forward-looking agenda that connects Brazilian research to international trends, fostering collaboration, interdisciplinarity, and greater global visibility for the field. A qualitative, longitudinal review of all A&FR articles related to Actuarial Science (2006-2025) was conducted. The analysis combined bibliographic mapping, thematic classification, and methodological assessment to identify dominant topics, emerging trends, and structural research gaps. This article offers a comprehensive historical mapping of actuarial research published in the A&FR from 2006 to 2025, analyzing 47 articles. The findings reveal a consistent focus on social security and pension sustainability, complemented in recent years by diversification toward insurance and financial risks, solvency, and regulation. The paper highlights the growing methodological sophistication of actuarial studies and identifies emerging research frontiers (e.g., health insurance, climate and cyber risks, and International Financial Reporting Standards-based solvency frameworks) that connect Actuarial Science to global debates on financial stability and sustainability.

Keywords: Actuarial Science, insurance, pensions, finance, risk management.

Correspondence address

João Vinícius de França Carvalho

Universidade de São Paulo, Faculdade de Economia, Administração, Contabilidade e Atuária,
Departamento de Contabilidade e Atuária
Professor Luciano Gualberto, 908, prédio FEA 3, sala 243 – CEP: 05508-010
Cidade Universitária – São Paulo – SP – Brazil

This is a bilingual text. This article has also been translated into Portuguese, published under the DOI [10.1590/1808-057x2026100-6.pt](https://doi.org/10.1590/1808-057x2026100-6.pt)

This article was specially prepared by the author for inclusion in the *Accounting & Finance Review*'s 100th Edition, at the invitation of the General Editor-in-Chief.



Admiráveis Riscos Novos: Traçando a evolução da pesquisa atuarial na Revista Contabilidade & Finanças até as fronteiras das Ciências Atuariais

RESUMO

O presente artigo tem como objetivo examinar a evolução temática e a trajetória metodológica das pesquisas sobre Ciências Atuariais publicadas na Revista Contabilidade & Finanças (RC&F), avaliar suas principais contribuições intelectuais e apontar caminhos promissores para pesquisas futuras. Apesar de sua relevância, as pesquisas sobre atuária no Brasil permaneceram fragmentadas, com integração limitada entre os estudos tradicionais sobre previdência e domínios emergentes, como a análise de seguros, as finanças climáticas e a gestão de riscos. Nenhum estudo anterior no Brasil mapeou sistematicamente esses desenvolvimentos ou articulou uma agenda de pesquisa unificada que relacionasse a Atuária às finanças, Contabilidade e sustentabilidade. Ao documentar a contribuição histórica da RC&F e delinear direções futuras, este estudo amplia a compreensão de como a pesquisa em Atuária pode abordar novos desafios sociais e regulatórios. Ele mostra o potencial da disciplina para fortalecer as políticas públicas, aumentar a resiliência financeira e apoiar a regulamentação baseada em evidências. O artigo posiciona a RC&F como uma plataforma fundamental para a publicação de artigos sobre Atuária na América Latina e propõe uma agenda voltada para o futuro, conectando a pesquisa brasileira às tendências internacionais e promovendo a colaboração, a interdisciplinaridade e uma maior visibilidade global para a área. Para tanto, foi realizada uma revisão qualitativa e longitudinal de todos os artigos da RC&F relacionados à Atuária (2006-2025). A análise combinou mapeamento bibliográfico, classificação temática e avaliação metodológica para identificar tópicos dominantes, tendências emergentes e lacunas estruturais na pesquisa. O artigo oferece um mapeamento histórico abrangente dos estudos atuariais publicados na RC&F entre 2006 e 2025, com análise de 47 artigos. Os resultados revelam um foco consistente na sustentabilidade da previdência social, das aposentadorias e das pensões, complementado, nos últimos anos, pela diversificação em direção a riscos financeiros e de seguros, solvência e regulamentação. O artigo destaca a crescente sofisticação metodológica dos estudos atuariais e identifica novas fronteiras de pesquisa, como seguros de saúde, riscos climáticos e cibernéticos, e estruturas de solvência baseadas nas International Financial Reporting Standards, conectando a Atuária aos debates globais sobre estabilidade financeira e sustentabilidade.

Palavras-chave: atuária, seguros, previdência, finanças, gestão de riscos.

1. INTRODUCTION

Actuarial Science is dedicated to the study of one of the most pervasive and complex elements in nature: risk. Although present across all domains of life and socioeconomic systems, risk remains challenging to comprehend due to its dynamic nature and interaction with multiple layers of uncertainty. The study of risk involves not only the analysis of measurable and controllable phenomena but also engagement with events that are intrinsically unpredictable and shaped by external variables. Economic, organizational, and individual decisions are all, to varying degrees, exposed to stochastic events capable of producing favorable or adverse outcomes. In light of the fundamental uncertainty that characterizes the future, effective risk mitigation and management require structured planning and rigorous methodological approaches grounded in quantitative and statistical modeling.

Within this context, actuarial research plays a key role. It enables both the identification and modeling of risks and the development of strategies to minimize undesirable impacts and ensure the sustainability of

financial, insurance, pension, and corporate systems. Continuously fueled by the emergence of new contingent events, Actuarial Science remains in constant demand, reaffirming its relevance in addressing the complex challenges posed by uncertainty.

Although actuarial practices date back to antiquity – with evidence of social security arrangements in the Roman Empire and compensation for commercial losses in Babylon – the formalization of Actuarial Science as a scientific discipline is marked by two major historical milestones. The first was Halley's (1693) publication of the earliest known mortality table based on empirical data, laying the foundation for the mathematical modeling of personal insurance and pension systems and widely recognized as a cornerstone of the field.

In the property and liability insurance sector, the modeling of financial fluctuations inherent to insurance operations became feasible with the consolidation of probabilistic and stochastic frameworks developed between the late 19th and mid-20th centuries. As noted by Bowers et al. (1997), Ruin Theory emerged as a

foundational area of non-life actuarial mathematics, initially formulated by Lundberg (1903) and further developed by Cramér (1930). These contributions gave rise to Collective Risk Theory, which provides the theoretical basis for modeling aggregate claims and evaluating ruin probabilities in insurance portfolios.

In this article, I aim to examine the thematic evolution of Actuarial Science research published in the *Accounting & Finance Review* (A&FR), while identifying emerging topics with potential for future scholarly exploration. To this end, I conducted a comprehensive review of 47 articles directly related to Actuarial Science published in the journal, beginning with the first two contributions in regular issues from 2006 and including the special edition of that same year, issued in celebration of the reopening of the undergraduate program in Actuarial Science. The sample was identified through a systematic examination of all A&FR issues published from 2006 to 2025. Articles

were included if they explicitly belonged to the Actuarial Science area or addressed actuarial-related topics (i.e., pensions, insurance, solvency, or risk management), even when originally classified under Finance or Accounting before the formal establishment of the Actuarial Science research track in 2011.

My analysis considers contextual and institutional factors behind the historical predominance of Social Security research. It also explores the intersection between actuarial and financial perspectives in Open and Closed Pension Funds and the recent thematic diversification toward insurance companies and innovative actuarial products. Finally, I outline future research avenues in Actuarial Science, emphasizing the increasing influence of internationalization – driven by the harmonization of global regulatory frameworks and the growing integration between academic research and the international actuarial profession.

2. A LOOK AT THE PAST: EVOLUTION OF ACTUARIAL RESEARCH IN THE A&FR

2.1 Internal Contextual Elements

The development of actuarial education and research in Brazil is closely tied to the institutional trajectory of the Department of Accounting and Actuarial Science at the School of Economics, Business, Accounting and Actuarial Science of the University of São Paulo (Faculdade de Economia, Administração, Contabilidade e Atuária da Universidade de São Paulo [FEA-USP]). The origins of actuarial education at the institution date back to Decree-Law n. 15.601 (1946, January 26), which established the then School of Economic and Administrative Sciences (Faculdade de Ciências Econômicas e Administrativas [FCEA]) of USP. Initially, FCEA was authorized to offer two undergraduate programs: (i) Economics and (ii) Accounting and Actuarial Science. Although formally coexisting, the two programs were originally offered as a single unified course. The legal separation of the programs into two distinct degrees (Actuarial Science and Accounting) was only formalized through Law 1.401, of July 31, 1951. However, the academic and administrative structures of both programs remained intertwined until 1964, when Ordinance GR n. 8 (1964, January 17) instituted an administrative reform granting them full independence.

Despite this formal separation, the autonomy of the Actuarial Science program was severely affected in the late 1980s, largely due to the prevailing macroeconomic conditions in Brazil. The period was marked by profound economic instability and a succession of anti-inflationary

plans, which rendered long-term financial planning unfeasible – a core function of the actuarial profession, particularly in the field of social security. The resulting decline in demand for actuaries, combined with a shortage of faculty specialized in actuarial mathematics and a drop in student interest, led to the program's deactivation at FEA-USP in 1990.

The undergraduate program remained suspended from 1993 to 2005 and was reinstated in 2006. As part of the celebrations marking its reactivation, the A&FR published a special edition that year, dedicated entirely to Actuarial Science. In the editorial, Professor Iran Siqueira Lima outlined the main motivations for the program's reinstatement, emphasizing: (i) the emergence of new actuarial products beyond traditional personal insurance; (ii) the impact of globalization on the insurance industry; (iii) the rise in risks associated with social insecurity and violence, and; (iv) increasing competition in the insurance market. These dynamics contributed to the expansion of the insurance sector and broadened its social relevance beyond conventional segments such as life, auto, and home insurance. The growing need for qualified professionals to assess and manage complex risks led to the establishment of new actuarial programs, particularly in the state of São Paulo, and the expansion of enrollment in existing ones.

From the creation of *Caderno de Estudos* (precursor to the A&FR) in 1989 until the journal's rebranding in 2001, few publications were explicitly devoted to Actuarial Science, though some addressed related themes. Among them, Kimura and Perera (2005) stand out for

proposing a risk management optimization model that identified hedging strategies to maximize expected returns. In a related area, Arraes and Rocha (2006) employed statistical tools from Extreme Value Theory to forecast maximum expected losses in stock index series, an approach consistent with actuarial risk modeling (Carvalho & Oliveira, 2024). Bezerra and Corrar (2006) were the only authors before the 2006 special edition to directly address the insurance sector, analyzing financial indicators that explained firm performance using factor analysis techniques.

2.2 2006: The Special Edition that Launched the Actuarial Science Track

As previously noted, the 2006 special edition of the A&FR marked a symbolically and institutionally significant moment: the reestablishment of the undergraduate program in Actuarial Science at FEA-USP. More than a milestone in academic administration, this relaunch represented a strategic repositioning of actuarial education in Brazil, in response to the increasing complexity of pension, insurance, and long-term financial systems. The edition assembled contributions that not only reflected the thematic breadth of the field but also showcased the growing methodological sophistication and maturity of actuarial research. By integrating theoretical studies, empirical analyses, and modeling approaches, the special issue fostered dialogue among academic scholarship, public policy development, and professional practice.

A recurring concern in published articles was the sustainability and effectiveness of risk measurement tools in social security systems. Fontoura et al. (2006) and Zylberstajn et al. (2006) examined, respectively, the structural challenges of the civil servants' pensions and the feasibility of universal reforms to the General Social Security Regime. Other papers addressed core pension fund management topics: Saad and Ribeiro (2006) analyzed asset-liability management (ALM) strategies, while Rodrigues (2006) discussed actuarial deficit amortization mechanisms. Both studies reflected the principles of prudence and intertemporal rationality, which are foundational to the actuarial approach to long-term financial commitments.

Within the edition, only two papers addressed the (re) insurance sector directly. Macedo et al. (2006) evaluated insurers' performance using Data Envelopment Analysis (DEA), combining profitability and risk metrics to define sector-specific benchmarks. Notably, the issue also featured the journal's first – and so far, only – contribution from international authors: Powers and Shubik (2006) introduced

the Square Root Rule as a guideline for determining the optimal number of reinsurers in a competitive market, highlighting equilibrium conditions between primary insurers and reinsurers. This contribution marked an important step in linking Brazilian actuarial research to international reinsurance theory and market dynamics.

By emphasizing both conceptual rigor and applied relevance, the 2006 special edition reinforced the critical role of academic training and research in developing sustainable social protection and financial systems. The reinstatement of the Actuarial Science program at FEA-USP thus went beyond reopening an undergraduate course: it revived a center of excellence dedicated to preparing professionals for the complex and dynamic challenges of contemporary actuarial practice.

A few years later, in 2011, the A&FR formally recognized Actuarial Science as one of its thematic areas, marking a new stage in the field's institutional consolidation within the journal. This milestone strengthened the A&FR's position as a leading outlet for actuarial research in Brazil.

2.3 The Evolution of Research

Over the years, actuarial research published in the A&FR has largely focused on the challenges facing pension systems. This emphasis reflects dominant concerns in Brazilian public finance, which culminated in the 2019 Pension Reform (Afonso & Carvalho, 2021). The predominance of studies on the sustainability of Social Security and public pension schemes, particularly the Pension Funds for Public Servants (RPPS), illustrates this trend. Out of the 47 articles identified as related to Actuarial Science of all times, 20 focus directly on social security topics, the first under the new track being Lima et al. (2012).

These studies address diverse issues, including the historical development of Brazil's pension system (Martins, 2020), fiscal impacts (Lima et al., 2012), distributive effects (Reis et al., 2015), and the adequacy of system design and underlying assumptions (Caldart et al., 2014; Gouveia et al., 2018). Other studies examine demographic dynamics such as mortality and dependency ratios (Bertho et al., 2024; Gonzaga et al., 2022; Souza, 2020), financial resilience (Lima & Aquino, 2019), and retirement preparedness (Vieira et al., 2023). Collectively, they reveal a strong concern with the long-term sustainability of pension regimes and the adequacy of actuarial assumptions for local demographic realities.

A growing body of literature has examined Pension Funds, focusing on both Closed (EFPC) e Open (EAPC) pension entities. Campani and Brito (2017), Flores et

al. (2021), Kataoka and Carmona (2024), and Soares and Campani (2020) analyze fund performance and behavior under regulatory constraints and investment practices, including passive strategies and alternative assets. Punsuvo et al. (2007) explore pension fund activism and corporate governance mechanisms, while Nascimento and Albuquerque (2021) study the financing of non-programmed benefits in defined contribution plans. Souza (2019) estimates upper and lower bounds for the expected present value of life annuities and insurance products under demographic uncertainty. Further studies assess how regulatory changes and alternative investment strategies affect pension fund performance and efficiency (Cardoso et al., 2024; Paula & Iquiapaza, 2022; Teixeira et al., 2025), highlighting a more integrated dialogue between financial performance and pension fund governance.

In insurance and risk management, the A&FR has opened space for notable contributions. Chan and Marques (2017) analyze market risk measurement, while Duarte et al. (2015) examine the impact of interest rates on liability adequacy. Peres et al. (2019) offer pricing insights for automobile insurance, Ikeda and Carvalho (2022) assess the market viability of innovative products such as Universal Life, and Gomes and Carvalho (2025) evaluate the effect of the COVID-19 pandemic on the business interruption market. Salotti and Carvalho (2024)

apply the cash flow at risk methodology to assess solvency in non-financial firms. Earlier studies by Carneiro and Sherris (2008), Kimura and Perera (2005), Leone et al. (2007), and Santos and Coelho (2018) examine risk measurement, Enterprise Risk Management (ERM), and disclosure practices in listed firms, aligning with the global trend toward integrated risk management frameworks.

With the advancement of International Accounting Standards (IAS), the A&FR has incorporated discussions on insurance accounting, particularly technical reserves and International Financial Reporting Standards (IFRS) implementation. Carvalho and Carvalho (2019) examine methods for estimating technical provisions, highlighting how methodological choices affect financial outcomes and capital adequacy. Signorelli et al. (2022) analyze the adoption of IFRS 17 in Brazil, highlighting the challenges associated with recognizing, measuring, and disclosing insurance contracts under the new standard. Paisano et al. (2025) explore the determinants of hybrid financial instruments issuance by insurers. Together, these studies underscore the importance of robust accounting practices that transparently reflect insurers' risks and ensure alignment with global regulatory and reporting standards.

As shown in Table 1, the evolution of actuarial publications in the A&FR reflects the broader institutional development of the field in Brazil. In the early years (2006-2010),

Table 1

Overview of Actuarial Science publications in the Accounting & Finance Review (A&FR) (2006-2025)

Period	Number of articles	Predominant themes	Methodological approach	Main contributions and trends
2006-2010	12	Social security; pension funds; actuarial sustainability; financial balance of public pension schemes.	Mathematical modeling and actuarial simulations; theoretical essays and public policy analyses.	Consolidation of the pension agenda and institutionalization of actuarial research; focus on solvency and system sustainability.
2011-2015	8	Complementary pension plans; fund governance; actuarial regulation; asset and liability management.	Statistical and econometric modeling; time-series analysis and value-at-risk.	Continuation of the pension agenda and expansion of analyses on pension funds; beginning of dialogue with the public finance literature.
2016-2020	10	Closed and open pension plans; actuarial finance; market risk; solvency.	Statistical and econometric models; data envelopment analysis, time-series analysis; and value-at-risk.	Thematic diversification; greater methodological sophistication; integration between actuarial science and quantitative finance.
2021-2025	17	Pension sustainability; actuarial reforms; fiscal impact assessment; population aging; regulation.	Actuarial simulations; modeling of actuarial cash flows; sensitivity analyses; institutional case studies; regression models.	Continued focus on pension issues, now with higher technical refinement and stronger articulation among actuarial science, public finance, and social policy; emergence of studies on regulation and international standards.
2006-2025	47	Historical predominance of pension-related themes, with gradual expansion toward insurance, actuarial finance, and regulation.	Mostly quantitative and applied methods with progressive technical sophistication.	The A&FR serves as a reference venue for actuarial research focused on the sustainability of pension systems and the strengthening of social protection policies in Brazil.

Source: *Elaborated by the author.*

research consolidated actuarial education and focused primarily on the sustainability of pension systems, whereas from 2016 onward the scope gradually expanded to encompass finance and risk modeling, signaling growing professionalization and the adoption of more advanced statistical methods.

Although actuarial studies have maintained a relatively stable share of the journal's total output (around 9% in 2006-2010, 8% in 2011-2015, 7% in 2016-2020, and nearly 9% in 2021-2025 – totaling 47 out of 549 published articles, or about 9% overall), their scholarly quality and thematic diversity have increased notably, reflecting the field's broadening scope over time.

In recent years, studies have become both more methodologically sophisticated and thematically diverse, addressing topics such as technical provisions, IFRS 17,

insurance products, and market risk assessment. Yet the core production remains rooted in demographic and pension issues, reflecting a mature research tradition that continues to evolve toward broader intersections with insurance, finance, and ERM.

In this context, a gradual expansion of dialogue with the international research agenda offers an opportunity to strengthen the A&FR. Leading actuarial journals have increasingly addressed topics such as climate and cyber risks, as well as systemic risk assessment (Araujo et al., 2026). This growing diversification also underscores how actuarial research increasingly converges with Finance and Accounting, as scholars combine valuation, solvency, and disclosure perspectives to address shared questions of risk and performance.

3. A LOOK TO THE FUTURE: WHAT TO EXPECT FROM RESEARCH IN ACTUARIAL SCIENCE?

The future of actuarial research (i.e., the scientific and practical contributions the A&FR can offer) depends on conceptual and methodological expansion beyond traditional pension themes. This evolution involves integrating new risk dimensions and emerging analytical approaches capable of capturing the economic, demographic, and technological transformations redefining the actuarial profession in the 21st century. The following sections present promising avenues for research aligned with international literature.

3.1 Supplementary Health Risks and the Health Insurance Cost Spiral

In Brazil, supplementary health insurance covers about a quarter of the population under the regulation of the National Supplementary Health Agency (Agência Nacional de Saúde Suplementar [ANS]) but faces rising costs, judicialization, and market concentration (Areias & Carvalho, 2021; Maia & Carvalho, 2020). High medical inflation, aging, and weak incentives for prevention threaten solvency and affordability, making the Brazilian context ideal for actuarial studies on pricing, reinsurance, and sustainable payment models.

Despite noteworthy progress in Brazil's actuarial research on pensions and solvency, the field of health insurance has remained relatively neglected. The contrast is clear: while the effects of the COVID-19 pandemic have been widely studied, the debate on the sustainability of supplementary healthcare is fragmented, even as costs rise and threaten the system's continuity.

In recent years, the supplementary health sector (both in Brazil and globally) has faced a critical mix of structural pressures: population aging, rising chronic diseases, medical inflation exceeding general inflation, fraud, litigation, and the rapid spread of high-cost diagnostic and therapeutic technologies (Li et al., 2022; Wu et al., 2022). The result is a claims spiral that strains insurers' technical reserves, weakens solvency (Areias & Carvalho, 2021), and gradually excludes beneficiaries as premiums rise beyond families' ability to pay (Maia & Carvalho, 2020). This scenario offers fertile ground for research integrating cost prediction, incentive design, prudential regulation, and risk-sharing mechanisms.

The first research front involves modeling medical inflation and claim frequency and severity more accurately by combining Actuarial Science and data analytics. Studies show that predictive models capable of identifying high-need, high-cost users outperform traditional methods by offering more precise risk estimates and better inputs for pricing and provisioning (de Ruijter et al., 2022). Another promising line concerns refining cost and productivity measures to decompose the effects of volume, price, and mix, thus avoiding bias in estimating the "real" cost of healthcare (Puiu & Bilbiie, 2025).

A second front concerns the redistributive effects of premium adjustments and risk equalization mechanisms. In regulated markets, well-calibrated risk equalization can mitigate adverse selection and smooth distortions caused by adjustments based on age or risk profiles (van Kleef et al., 2024). However, excessive cost-sharing arrangements (e.g., copayments and deductibles) can

discourage the appropriate use of healthcare services and worsen inequality of access, with regressive effects on vulnerable groups (van de Ven et al., 2023). The key challenge is balancing solidarity and efficiency without turning exclusion into a pricing issue, especially in the context of new technologies (Espinosa & Zarruk, 2021).

A third avenue may examine how regulation affects insurers' solvency and incentives for disease prevention before chronic conditions develop (Stocking et al., 2025). Evidence suggests that replacing fee-for-service models with value-based payment systems (e.g., bundled payments, capitation, or pay-for-performance) can reduce costs (Stadhouder et al., 2019) while maintaining or even improving quality, provided that risk adjustment and performance monitoring remain robust (Kadakia & Offodile, 2023). In Brazil, this opens a comparative research agenda exploring how ANS regulations, pricing rules, and prudential requirements can align with health-value metrics, integrating prevention, coordinated care, and financial stability.

Finally, a fourth avenue involves exploring risk-sharing mechanisms through reinsurance (Areias & Carvalho, 2021). To contain the premium spiral without distorting care, a multilayered approach could be developed: (i) a stop-loss by beneficiary and in aggregate to protect against high-cost losses; (ii) quota-share and high-risk pools to reduce concentration and avoid abrupt premium adjustments; and (iii) state-sponsored reinsurance and risk corridors for rare, high-impact shocks. Recent studies show that subsidized reinsurance programs can reduce premiums and keep insurers in the market, although effects vary depending on design (Fung et al., 2023; Oyeka & Wehby, 2023). Prospective risk pools that spread costs across predictably high-cost cohorts can neutralize adverse selection at low administrative cost when well calibrated (Withagen-Koster et al., 2024). Ex ante frameworks also allow regulators to test triggers, coinsurance, and funding models before implementation, reducing design errors (van Kleef et al., 2024).

3.2 Climate Risks: Catastrophe Management and the Role of Actuarial Science

Accelerating climate change has turned environmental risk into actuarial risk (Dionne & Desjardins, 2022). The growing frequency and severity of extreme events (e.g., droughts, floods, frosts, and heat waves) have reduced the predictability that supported traditional pricing models based on historical stability. As variance and correlation between events increase, shocks become more systemic, breaking the independence assumption that once

sustained mutual insurance. As Courbage and Golnaraghi (2022) note, the "low-frequency, high-severity" pattern has been replaced by a sequence of medium-scale shocks whose cumulative effects generate lasting fiscal pressures.

Brazil's economy and fiscal balance are highly exposed to climate variability, particularly through agribusiness (Carvalho et al., 2025). With agricultural production accounting for about 6.9% of gross domestic product, programs such as the Rural Insurance Premium Subsidy need actuarial models to improve pricing accuracy, to expand coverage, and to stabilize public spending on disasters, thereby enhancing climate resilience through (re)insurance.

This transformation calls for new approaches to modeling and governance. Actuarial Science can bridge statistics and economics by quantifying risks to support public policy. Measuring climate risks is no longer a retrospective task of estimating probabilities, but a forward-looking exercise that integrates climatic and socioeconomic data to anticipate scenarios and estimate the costs of inaction.

Agriculture illustrates this link well. It is the sector most exposed to climate variability and also the most socially sensitive, given its role in food security and price stability. Carvalho et al. (2025) argue that climate impacts on rural production trigger a chain reaction that reduces income, squeezes margins, affects credit, and forces governments into fiscally unsustainable ex post interventions. This dependence on reactive responses reflects a structural failure: the absence of actuarial mechanisms that convert climate variability into insurable risk.

Agricultural insurance thus serves as a bridge between climate and fiscal agendas. When properly designed, it acts as a preventive risk-transfer instrument, replacing uncertain public spending with predictable premium payments. This shift changes the timing of disaster response: instead of mobilizing resources after losses occur, it mobilizes financing before they happen. Parametric insurance, based on observable meteorological indices, marks a significant methodological step forward (Abdi et al., 2022; Wijesena & Pradhan, 2025). By reducing verification costs, mitigating information asymmetry, and providing quick liquidity, these products expand coverage and reduce governments' fiscal vulnerability.

However, strengthening this first layer of protection requires effective mechanisms for global risk redistribution. As Subramanian and Wang (2018) highlight, as event correlations and aggregate losses grow, reinsurance treaties and Insurance-Linked Securities (ILS) become complementary. Reinsurance transfers part of the exposure to global markets, preserving the solvency of local insurers,

while catastrophe bonds (whose payments are triggered by disasters) connect capital markets to the insurance sector.

This integration between (re)insurance and capital-market instruments creates a financial resilience system that enhances countries' adaptive capacity to climate risks. In developing countries (such as Brazil), where insurance penetration is low and fiscal capacity limited, such instruments allow part of the risk to be transferred to global investors, turning vulnerability into a financial asset and reducing the burden on the state as payer of last resort.

The main challenge is coordination. These mechanisms depend on transparent and reliable actuarial models capable of estimating expected losses, defining objective triggers, and properly pricing extreme risks. This is precisely where Actuarial Science contributes: by integrating insurance and finance to improve resource allocation (Araujo et al., 2026; Dionne & Desjardins, 2022).

Beyond their microeconomic effects (e.g., stabilizing farmers' income), agricultural insurance and related financial instruments also play a macroeconomic role. By preventing climate losses from turning into credit defaults, they help maintain financial flows even in crisis years. Actuarial modeling provides the data needed for governments, insurers, and reinsurers to design stabilization funds, subsidy programs, and sovereign guarantees.

This forward-looking and integrated logic also supports next-generation climate-finance instruments, such as Resilience Bonds (Motlagh et al., 2024), Catastrophe Bonds (Li & Su, 2024), and Environmental Impact Bonds (Trotta, 2024). These instruments form a new class of financial solutions designed to price, transfer, and mitigate climate risks in an integrated way. Catastrophe Bonds transfer extreme risk from insurers to capital markets, allowing investors to absorb natural disaster losses in exchange for higher returns when no event occurs. Resilience Bonds combine infrastructure financing with future reductions in insurance premiums, effectively monetizing mitigation: investments that reduce vulnerabilities (e.g., urban drainage systems, slope containment, flood barriers) generate actuarial savings that help finance the projects themselves. Environmental Impact Bonds, in turn, follow a pay-for-success logic, linking investor returns to measurable environmental outcomes such as reduced stormwater runoff, carbon sequestration, or restoration of degraded areas.

Although they differ in structure, all share the same rationale: aligning climate finance with measurable risk reduction and strengthening the financial resilience of governments and communities. Recent literature shows that this convergence between actuarial pricing,

sustainable finance, and public policy is redefining the frontier of the field (Barrera & Wagner, 2023).

In summary, the growing connection among climate risks, agricultural insurance, reinsurance, and financial instruments reflects a shift in Actuarial Science – from measuring risks to managing them. Actuarial research can now combine technical predictability, fiscal discipline, and fairness. This marks a new stage in which climate risk is not only priced but also managed, and insurance becomes a tool of public policy.

3.3 Cyber Risks and Insurance: New Frontiers for Actuarial Research

The rapid expansion of the digital economy has increased organizational exposure to cyber incidents, introducing a category of systemic and hard-to-measure risk. Brazil's digital economy faces rising ransomware attacks and stricter liability under the General Data Protection Law (LGPD). With limited cyber-insurance offerings and evolving Superintendence of Private Insurance (SUSEP) regulation (e.g., National Council of Private Insurance Resolution n. 471/2024), the market remains at an early stage, offering opportunities for actuarial research on pricing, capital requirements, and governance models that can foster a more mature and resilient cyber-risk ecosystem.

Recent research in Actuarial Science and finance has focused on understanding these risks and their implications for solvency, insurance pricing, and regulatory capital. Three major reviews (Eling, 2020; Eling et al., 2021; He et al., 2024) outline the main advances, challenges, and research opportunities in this field.

Eling (2020) offers one of the first systematic reviews of cyber risk and insurance research, highlighting fragmented data, the absence of standardized classifications, and challenges in modeling event dependencies – all of which hinder aggregate loss estimation. Although progress has been made in estimating incident frequency and severity, most models still underestimate systemic potential, i.e., correlated, simultaneous events capable of causing major financial impacts.

Although organizations increasingly recognize cyber risk as a strategic concern, its integration into traditional solvency and capital metrics remains in its early stages. Eling et al. (2021) argue that, although companies recognize cyber risk as strategic, its integration into solvency and capital frameworks remains limited. They propose a conceptual framework that embeds cyber risk into ERM and call for studies linking mitigation decisions (e.g., investments in security and incident response) to actuarial measurement of residual risk. They also point

to the potential of alternative risk-transfer mechanisms, such as ILS and cyber catastrophe bonds, which allow reinsurers and capital-market investors to share exposure (Braun et al., 2023).

He et al. (2024) broaden the methodological scope by reviewing over 200 studies published from 2010 to 2023 from fields such as Actuarial Science, Computer Science, and risk management. They propose a research taxonomy covering: (i) prediction, encompassing the use of machine learning, graph-based models, and time-series analysis to anticipate attacks and vulnerabilities; (ii) risk modeling, focusing on the measurement of potential losses through severity distributions, copulas, and extreme value theory, and; (iii) risk management and insurance, addressing the economic, contractual, and regulatory implications of risk transfer. A key insight is that machine learning and network models are not yet fully integrated into actuarial applications, particularly in pricing and capital estimation. This gap offers a promising research path, combining traditional statistical tools with predictive algorithms to improve tail-risk estimation based on complex network vulnerabilities (Carvalho & Guimarães, 2024).

The frontier of cyber risk research in Actuarial Science centers on four major challenges. The first is quantitative and empirical: developing broader, standardized databases that allow risk stratification by incident type, sector, and interdependence among agents. The second is methodological: integrating classical frequency-severity models with statistical and network learning approaches to capture contagion dynamics, failure cascades, and nonlinear dependencies. The third is economic and contractual: designing pricing frameworks that internalize the endogeneity of security investments (i.e., how preventive actions affect insured risk) while mitigating adverse selection and moral hazard. Finally, the fourth is institutional and regulatory: assessing how risk-based solvency regimes (Cotticelli & Savelli, 2024; Eling & Schnell, 2020) can be adapted to the dynamic and correlated nature of cyber risks.

These gaps outline a promising research agenda for the A&FR and the Brazilian actuarial community. They call for studies integrating extreme value theory, conditional copulas, graph-based Monte Carlo simulations, and technical vulnerability indicators (e.g., system failures, outsourcing of critical services) to better understand loss distribution tails. Institutional opportunities also arise for research on data-sharing mechanisms, parametric triggers in risk-transfer instruments, and the regulatory implications of mandatory incident reporting.

For the A&FR, promoting dialogue between Actuarial Science, Finance, and Data Science offers a unique

opportunity to advance knowledge at the intersection of these fields and to contribute meaningfully to global discussions on financial stability and risk governance.

3.4 Regulation, Solvency, and Accounting Standards under New Demands

The evolution of IAS has been key in building a more integrated and forward-looking risk-management culture (Carvalho, Freitas, & Bohnert, 2025). IFRS 9, IFRS 17, and the recent sustainability standards IFRS S1 and IFRS S2 represent a broader shift toward incorporating risk (financial, actuarial, and environmental) into corporate decision-making and market disclosure. Each introduces new analytical demands and fosters stronger links between Accounting, Finance, and Actuarial Science.

IFRS 9 redefined credit-risk accounting by replacing the backward-looking IAS 39 model with the forward-looking Expected Credit Loss (ECL) approach. This shift aligned accounting with probabilistic reasoning, requiring early loss recognition and the inclusion of macroeconomic scenarios. As a result, stochastic modeling and simulation techniques became key tools, opening opportunities for research on how ECL adoption affects financial stability, capital efficiency, and credit allocation across contexts (Kyi & Tawiah, 2025).

IFRS 17, in turn, marks a breakthrough in the measurement of insurers' liabilities. By replacing IFRS 4, this standard introduced a forward-looking approach based on the present value of future cash flows and an explicit adjustment for non-financial risk, designed to capture uncertainties related to claims and technical provisions. This shift brings accounting closer to actuarial logic by recognizing the stochastic and intertemporal nature of insurance contracts. Moreover, it introduces a degree of professional judgment and discretion (e.g., in the choice of methodologies for measuring the risk adjustment) that opens space for debates on transparency, comparability, and potential incentives for earnings-smoothing practices.

These issues provide fertile ground for empirical and theoretical research aimed at examining the informational effectiveness of IFRS 17, its interaction with prudential frameworks such as Solvency II, and the role of actuarial methods in mitigating measurement biases (Carvalho & Carvalho, 2024; Palmborg et al., 2021; Puławska & Strzelczyk, 2025). In addition, the standard brings back into focus the issue of managerial opportunism: the subjectivity involved in methodological choices may create room for earnings management practices, warranting rigorous empirical investigation (Ding et al., 2020).

More recently, IFRS S1 and S2 – issued by the International Sustainability Standards Board (ISSB) – have extended risk disclosure to sustainability. IFRS S1 provides general guidelines for sustainability-related information, while IFRS S2 focuses on climate-related financial risks. This regulatory development incorporates physical, transition, and reputational risks into performance and solvency assessments, demanding scenario-based metrics and probabilistic analysis. Actuarial expertise is especially relevant for translating environmental and climate uncertainties into measurable financial indicators (Chabot, 2025; Seow, 2024). Empirical studies on the applicability of these models in emerging economies remain scarce.

Together, these standards illustrate the convergence of accounting and risk management, with Actuarial Science at the core. Using tools such as Monte Carlo simulations, copula-based dependence models, tail-risk measures (e.g., Tail VaR and Expected Shortfall), and hybrid approaches with machine learning can enhance the precision of estimates and reduce managerial discretion, improving transparency and comparability of financial reports.

For the A&FR, publishing papers regarding the effects of these standards offers rich opportunities for collaboration among actuaries, accountants, and finance scholars to advance financial stability and global risk governance.

3.5 Internationalization and Academic Collaboration Networks

Perhaps the clearest message from literature is that science is not built alone. Araujo et al. (2026) show that globally, more than 80% of actuarial studies are co-authored, with an average of four authors per paper.

4. FINAL REMARKS

The trajectory of actuarial research in the A&FR reflects the evolution of the field in Brazil, from an agenda centered on social security and private pensions to a broader and more integrated approach to financial risk. Over nearly 2 decades, the A&FR has become a leading forum for debate on solvency, financial sustainability, and regulation, contributing to the theoretical and methodological maturity of actuarial research in the country.

This article aimed not only to highlight the A&FR's historical relevance as a platform for actuarial knowledge but also its potential for thematic expansion and internationalization. By embracing new risk dimensions and strengthening bridges with finance, accounting, and

This pattern highlights that scientific progress depends on collaborative networks crossing national, institutional, and disciplinary boundaries.

Despite progress, Brazil's scientific output in Actuarial Science remains modest. The number of articles published by Brazilian authors is small compared with leading countries (Araujo et al., 2026), partly due to the relatively small size of the active academic community in the field, a reflection of the limited number of undergraduate programs. Until 2004, Brazil had only four such programs: Federal University of Rio de Janeiro (1945), Federal University of Rio Grande do Sul (1945), Pontifical Catholic University of São Paulo (1958), and Federal University of Ceará (2001). Currently, 18 universities offer undergraduate degrees in Actuarial Science, but the country still lacks dedicated graduate programs (master's and PhD-level) in the field. The main exception is the Graduate Program in Controllershship and Accounting (PPGCC) at FEA-USP, which includes a research track in Finance, Risk, and Actuarial Science and has played an important role in training a new generation of Brazilian researchers in life, non-life, and health insurance.

With stronger academic training and the growing number of PhD-level researchers, a more promising future for actuarial research in Brazil is within reach. Beyond increasing the volume and quality of publications, the goal is to create conditions for new collaborative networks to flourish, both domestically and internationally. Such expansion is fundamental to positioning Brazil more prominently in global scientific debates, fostering knowledge exchange, and consolidating a scholarly community capable of contributing originally and robustly to major debates on risk, pensions, and financial sustainability amid the challenges of the 21st century.

public policy, the journal can foster interdisciplinary research and broader impact.

The actuarial community is confident that the A&FR will continue to play a strategic role in disseminating new knowledge that combines technical rigor, social relevance, and global dialogue. By aligning with international research frontiers, Brazil can advance toward a more integrated, proactive, and socially meaningful research agenda. Strengthening these bridges between Actuarial Science, Finance, and Accounting will be essential to address the complex, interdependent risks that shape organizations and markets in the 21st century.

REFERENCES

- Abdi, M. J., Raffar, N., Zulkafli, Z., Nurulhuda, K., Rehan, B. M., Muharam, F. M., Khosim, N. A., & Tangang, F. (2022). Index-based insurance and hydroclimatic risk management in agriculture: A systematic review of index selection and yield-index modelling methods. *International Journal of Disaster Risk Reduction*, 67(October 2021), 102653. <https://doi.org/10.1016/j.ijdrr.2021.102653>
- Afonso, L. E., & Carvalho, J. V. F. (2021). Show do trilhão no RGPS? Quantificando os aspectos fiscais e distributivos da reforma da previdência do governo Bolsonaro. *Revista Brasileira de Economia*, 72(2), 1–20. <https://doi.org/10.5935/0034-7140.20210007>
- Araujo, T. D., Fonseca, N. C., & Carvalho, J. V. F. (2026). One headlight! Bibliometric analysis and text mining of scientific production in Actuarial Science in the Non-Life sector. *Brazilian Business Review*, 23.
- Areias, C. A. C., & Carvalho, J. V. F. (2021). Reinsurance in the Supplementary Health: A Counterfactual Study on the Impacts of Reinsurance Treaties Adoption by Healthcare Plans Operators in Brazil. *Brazilian Business Review*, 18(2), 217–235. <https://doi.org/10.15728/bbr.2021.18.2.6>
- Arraes, R. A., & Rocha, A. S. (2006). Perdas extremas em mercados de risco. *Revista Contabilidade & Finanças*, 17(42), 22–34. <https://doi.org/10.1590/s1519-70772006000300003>
- Barrera, L. I. A., & Wagner, J. (2023). A systematic literature review on sustainability issues along the value chain in insurance companies and pension funds. *European Actuarial Journal*, 13(2), 653–701. <https://doi.org/10.1007/s13385-023-00349-1>
- Bertho, A. C. S., Fernandes, N. S., Fonseca, T. C. O., Costa, B. A. S., & Peregrino, R. L. (2024). Seguros de pessoas e previdência complementar aberta no Brasil: Um estudo sobre os diferenciais de mortalidade por nível educacional. *Revista Contabilidade & Finanças*, 35(96). <https://doi.org/10.1590/1808-057x20241961.pt>
- Bezerra, F. A., & Corrar, L. J. (2006). Utilização da análise fatorial na identificação dos principais indicadores para avaliação do desempenho financeiro: uma aplicação nas empresas de seguros. *Revista Contabilidade & Finanças*, 17(42), 50–62. <https://doi.org/10.1590/S1519-70772006000300005>
- Bowers, N. L., Gerber, H. U., Hickman, J. C., Jones, D. A., & Nesbitt, C. J. (1997). *Actuarial Mathematics* (2nd.). Society of Actuaries.
- Braun, A., Eling, M., & Jaenicke, C. (2023). Cyber insurance-linked securities. *ASTIN Bulletin*, 684–705. <https://doi.org/10.1017/asb.2023.22>
- Caldart, P. R., Motta, S. T., Caetano, M. A.-R., & Bonatto, T. V. (2014). The Fitness of Assumptions and an Alternative Model for Funding the Public Sector Pension Scheme: The Case of Rio Grande do Sul. *Revista Contabilidade & Finanças*, 25(66), 281–293. <https://doi.org/10.1590/1808-057x201412200>
- Campani, C. H., & Brito, L. M. (2017). Private pension funds: passivity at active fund prices. *Revista Contabilidade & Finanças*, 29(76), 148–163. <https://doi.org/10.1590/1808-057x201804270>
- Cardoso, L., Carvalho, J. V. F., & Damasceno, A. T. (2024). Regulatory impacts on investments by Pension Funds in Brazil. *Revista Contabilidade & Finanças*, 35(96), 1–18. <https://doi.org/10.1590/1808-057x20241813.en>
- Carneiro, L. A. F., & Sherris, M. (2008). Corporate interest rate risk management with derivatives in Australia: empirical results. *Revista Contabilidade & Finanças*, 19(46), 86–107. <https://doi.org/10.1590/s1519-70772008000100008>
- Carvalho, B. D. R., & Carvalho, J. V. F. (2019). A stochastic approach for measuring the uncertainty of claims reserves. *Revista Contabilidade & Finanças*, 30(81), 409–424. <https://doi.org/10.1590/1808-057x201907860>
- Carvalho, B. D. R., & Carvalho, J. V. F. (2024). IFRS 17: a proposal for disclosing Liabilities for Incurred Claims in Notes to the Financial Statements. *Advances in Scientific and Applied Accounting*. <https://doi.org/10.14392/asaa.2024170205>
- Carvalho, J. V. F., Fonseca, N. C., & Bagatini, D. F. (2025). Um estudo sobre a diversificação espacial de riscos climáticos em seguros agrícolas no Brasil. *Estudos Econômicos*, 55(4), e53575546. <https://doi.org/10.1590/1980-53575546jnd>
- Carvalho, J. V. F., Freitas, L. C. B., & Bohnert, A. (2025). Beyond Finance: How New Accounting Standards Can Support Risk Management Practices. *Revista de Gestão*, 32(4), 1–5. <https://doi.org/10.1108/REGE-10-2025-217>
- Carvalho, J. V. F., & Guimarães, A. S. (2024). Systemic risk assessment using complex networks approach: Evidence from the Brazilian (re)insurance market. *Research in International Business and Finance*, 67, 102065. <https://doi.org/10.1016/j.ribaf.2023.102065>
- Carvalho, J. V. F., & Oliveira, L. H. A. (2024). We are Living on the Edge: Managing Extreme-Severity Claims Using Extreme Value Theory. *Brazilian Business Review*, 21(3), 1–22. <https://doi.org/10.15728/bbr.2022.1245.en>
- Chabot, M. (2025). Textual and AI-based analysis of climate disclosures: Evidence from the European energy sector. *The British Accounting Review*, 101736. <https://doi.org/10.1016/j.bar.2025.101736>
- Chan, B. L., & Marques, F. T. (2017). Impacts of the regulatory model for market risk capital: application in a special savings company, an insurance company, and a pension fund. *Revista Contabilidade & Finanças*, 28(75), 465–477. <https://doi.org/10.1590/1808-057x201703840>
- Cotticelli, S., & Savelli, N. (2024). Capital requirement modeling for market and non-life premium risk in a dynamic insurance portfolio. *Annals of Actuarial Science*, 18(1), 205–236. <https://doi.org/10.1017/S1748499523000234>
- Courbage, C., & Golnaraghi, M. (2022). Extreme events, climate risks and insurance. *The Geneva Papers on Risk and Insurance - Issues and Practice*, 47(1), 1–4. <https://doi.org/10.1057/s41288-021-00260-4>

- Cramér, H. (1930). On the Mathematical Theory of Risk. *Skandia Jubilee Volume*, Stockholm.
- de Ruijter, U. W., Kaplan, Z. L. R., Bramer, W. M., Eijkenaar, F., Nieboer, D., van der Heide, A., Lingsma, H. F., & Bax, W. A. (2022). Prediction Models for Future High-Need High-Cost Healthcare Use: a Systematic Review. *Journal of General Internal Medicine*, 37(7), 1763–1770. <https://doi.org/10.1007/s11606-021-07333-z>
- Ding, K., Lev, B., Peng, X., Sun, T., & Vasarhelyi, M. A. (2020). Machine learning improves accounting estimates: evidence from insurance payments. *Review of Accounting Studies*, 25(3), 1098–1134. <https://doi.org/10.1007/s11142-020-09546-9>
- Dionne, G., & Desjardins, D. (2022). A re-examination of the US insurance market's capacity to pay catastrophe losses. *Risk Management and Insurance Review*, 25(4), 515–549. <https://doi.org/10.1111/rmir.12228>
- Duarte, A. A., Silva, A. F., Oliveira, L. V., Weffort, E. F. J., & Chan, B. L. (2015). The Term Structure of Interest Rates and its Impact on the Liability Adequacy Test for Insurance Companies in Brazil. *Revista Contabilidade & Finanças*, 26(68), 223–236. <https://doi.org/10.1590/1808-057x201500420>
- Eling, M. (2020). Cyber risk research in business and actuarial science. *European Actuarial Journal*, 10(2), 303–333. <https://doi.org/10.1007/s13385-020-00250-1>
- Eling, M., McShane, M., & Nguyen, T. (2021). Cyber risk management: History and future research directions. *Risk Management and Insurance Review*, 24(1), 93–125. <https://doi.org/10.1111/rmir.12169>
- Eling, M., & Schnell, W. (2020). Capital Requirements for Cyber Risk and Cyber Risk Insurance: An Analysis of Solvency II, the U.S. Risk-Based Capital Standards, and the Swiss Solvency Test. *North American Actuarial Journal*, 24(3), 370–392. <https://doi.org/10.1080/10920277.2019.1641416>
- Espinosa, O., & Zarruk, A. (2021). The importance of actuarial management in insurance business decision-making in the twenty-first century. *British Actuarial Journal*, 26, e14. <https://doi.org/10.1017/S1357321721000155>
- Flores, F. A., Campani, C. H., & Roquete, R. M. (2021). The impact of alternative assets on the performance of Brazilian private pension funds. *Revista Contabilidade & Finanças*, 32(86), 314–330. <https://doi.org/10.1590/1808-057x202111870>
- Fontoura, F. R., Cardoso, S., Rocha, A. S., Capelo Júnior, E., & Câmara, S. F. (2006). Um modelo de avaliação de obrigações previdenciais de regimes capitalizados de previdência no serviço público. *Revista Contabilidade & Finanças*, 17(spe2), 42–55. <https://doi.org/10.1590/s1519-70772006000500004>
- Fung, D. W. H., Wei, P., & Yang, C. C. (2023). State subsidized reinsurance programs: Impacts on efficiency, premiums, and expenses of the U.S. health insurance markets. *European Journal of Operational Research*, 306(2), 941–954. <https://doi.org/10.1016/j.ejor.2022.08.005>
- Gomes, I. G. M., & Carvalho, J. V. F. (2025). Side effects of the pandemic: impacts on the business interruption insurance market. *Revista Contabilidade & Finanças*, 36(spe1). <https://doi.org/10.1590/1808-057x2024143.en>
- Gonzaga, M. R., Lima, E. E. C., Queiroz, B. L., Ansiliero, G., & Freire, F. H. M. A. (2022). Mortality differentials in beneficiaries of the National Institute of Social Security of Brazil in 2015. *Revista Contabilidade & Finanças*, 33(90), 1–17. <https://doi.org/10.1590/1808-057x20221556.en>
- Gouveia, A. L. L. A., Souza, F. C., & Rêgo, L. C. (2018). Actuarial fairness in social security calculations: application of a multiple decrement model to compare the social security factor and minimum age rules. *Revista Contabilidade & Finanças*, 29(78), 469–486. <https://doi.org/10.1590/1808-057x201805740>
- Halley, E. (1693). An estimate of the degrees of the mortality of mankind; drawn from curious tables of the births and funerals at the city of Breslaw; with an attempt to ascertain the price of annuities upon lives. *Philosophical Transactions of the Royal Society of London*, 17(196), 596–610. <https://doi.org/10.1098/rstl.1693.0007>
- He, R., Jin, Z., & Li, J. S.-H. (2024). Modeling and management of cyber risk: a cross-disciplinary review. *Annals of Actuarial Science*, 18(2), 270–309. <https://doi.org/10.1017/S1748499523000258>
- Ikedá, M. M. S., & Carvalho, J. V. F. (2022). Viability of Universal Life insurance in Brazil from the supply and demand perspectives. *Revista Contabilidade & Finanças*, 33(89), 343–358. <https://doi.org/10.1590/1808-057x202113720>
- Kadakia, K. T., & Offodile, A. C. (2023). The Next Generation of Payment Reforms for Population Health – An Actionable Agenda for 2035 Informed by Past Gains and Ongoing Lessons. *The Milbank Quarterly*, 101(S1), 866–892. <https://doi.org/10.1111/1468-0009.12632>
- Kataoka, S. S., & Carmona, C. U. M. (2024). Influence of the sponsor's financial situation on the allocation of pension plan assets. *Revista Contabilidade & Finanças*, 35(94). <https://doi.org/10.1590/1808-057x20231846.en>
- Kimura, H., & Perera, L. C. J. (2005). Modelo de otimização da gestão de risco em empresas não financeiras. *Revista Contabilidade & Finanças*, 16(37), 59–72. <https://doi.org/10.1590/s1519-70772005000100005>
- Kyiu, A., & Tawiah, V. (2025). IFRS 9 implementation and bank risk. *Accounting Forum*, 49(1), 234–258. <https://doi.org/10.1080/01559982.2023.2233861>
- Leone, R., Nascimento, R. Q., Leone, G. G., & Oliveira, P. (2007). Proposta de mensuração de risco baseado em utilidade. *Revista Contabilidade & Finanças*, 18(44), 23–32. <https://doi.org/10.1590/s1519-70772007000200003>
- Li, H., & Su, J. (2024). Mitigating wildfire losses via insurance-linked securities: Modeling and risk management perspectives. *Journal of Risk and Insurance*, 91(2), 383–414. <https://doi.org/10.1111/jori.12449>
- Li, J., Lan, Q., Zhu, E., Xu, Y., & Zhu, D. (2022). A Study of Health Insurance Fraud in China and Recommendations for Fraud Detection and Prevention. *Journal of Organizational and End User Computing*, 34(4), 1–19. <https://doi.org/10.4018/joeuc.301271>

- Lima, D. V., & Aquino, A. C. B. (2019). Financial resilience of municipal civil servants' pension funds. *Revista Contabilidade & Finanças*, 30(81), 425–445. <https://doi.org/10.1590/1808-057x201908810>
- Lima, D. V., Wilbert, M. D., Pereira, J. M., & Paulo, E. (2012). O impacto do fator previdenciário nos grandes números da previdência social. *Revista Contabilidade & Finanças*, 23(59), 128–141. <https://doi.org/10.1590/s1519-70772012000200005>
- Lundberg, F. O. (1903). Approximations of the Probability Function/Reinsurance of Collective Risks. *Almqvist and Wiksell*.
- Macedo, M. A. S., Silva, F. F., & Santos, R. M. (2006). Análise do mercado de seguros no Brasil: uma visão do desempenho organizacional das seguradoras no ano de 2003. *Revista Contabilidade & Finanças*, 17(spe2), 88–100. <https://doi.org/10.1590/s1519-70772006000500007>
- Maia, A. C., & Carvalho, J. V. F. (2020). A espiral de antisseleção no mercado brasileiro de planos de saúde individuais. *Estudo Econômico*, 50(3), 535–568. <https://doi.org/10.1590/0101-41615036amj>
- Martins, A. (2020). The actuarial profession and social security in Brazil from the First Republic up to the Vargas Era. *Revista Contabilidade & Finanças*, 31(83), 364–377. <https://doi.org/10.1590/1808-057x201909010>
- Motlagh, F., Hamideh, S., Gallagher, M., Yan, G., & van de Lindt, J. W. (2024). Bonds for disaster resilience: A review of literature and practice. *International Journal of Disaster Risk Reduction*, 104(March 2023), 104318. <https://doi.org/10.1016/j.ijdr.2024.104318>
- Nascimento, I. F., & Albuquerque, P. H. M. (2021). Fair and balance rate for benefits not scheduled in defined contribution plans. *Revista Contabilidade & Finanças*, 32(87), 560–576. <https://doi.org/10.1590/1808-057x202112630>
- Oyeka, O., & Wehby, G. L. (2023). Effects of state reinsurance programs on health insurance exchange premiums and insurer participation. *Health Services Research*, 58(5), 1077–1088. <https://doi.org/10.1111/1475-6773.14205>
- Paisano, B., Flores, E., & Salotti, B. M. (2025). Determinants of the issuance of hybrid securities by insurers from the perspective of IAS 32. *Revista Contabilidade & Finanças*, 36(97), e2123. <https://doi.org/10.1590/1808-057x20242123.en>
- Palmborg, L., Lindholm, M., & Lindskog, F. (2021). Financial position and performance in IFRS 17. *Scandinavian Actuarial Journal*, 3, 171–197. <https://doi.org/10.1080/03461238.2020.1823464>
- Paula, J. S., & Iquiapaza, R. A. (2022). Investment fund selection techniques from the perspective of Brazilian pension funds. *Revista Contabilidade & Finanças*, 33(88), 167–182. <https://doi.org/10.1590/1808-057x202113250>
- Peres, V. M., Maldonado, W. L., & Candido, O. (2019). Automobile insurance in Brazil: market concentration and demand. *Revista Contabilidade & Finanças*, 30(81), 396–408. <https://doi.org/10.1590/1808-057x201808300>
- Powers, M. R., & Shubik, M. (2006). A “square-root rule” for reinsurance. *Revista Contabilidade & Finanças*, 17(spe2), 101–107. <https://doi.org/10.1590/S1519-70772006000500008>
- Puiu, I.-A., & Bilbiie, A. (2025). Measuring productivity in the healthcare sector: a bibliometric and content analysis. *Health Economics Review*, 15(1), 24. <https://doi.org/10.1186/s13561-025-00612-z>
- Puławska, K., & Strzelczyk, W. (2025). IFRS 17 implementation: market participants' perspective. *Central European Management Journal*, 33(3), 455–477. <https://doi.org/10.1108/CEMJ-08-2023-0330>
- Punsuvo, F. R., Kayo, E. K., & Barros, L. A. B. C. (2007). Activism of Pension Funds and Corporate Governance Quality. *Revista Contabilidade & Finanças*, 18(45), 63–72.
- Reis, P. R. C., Silveira, S. F. R., Braga, M. J., & Costa, T. de M. T. (2015). Impact of Retirements and Pensions on the Social Welfare of the Households from Minas Gerais State. *Revista Contabilidade & Finanças*, 26(67), 106–118. <https://doi.org/10.1590/1808-057x201511890>
- Rodrigues, J. A. (2006). Modelos de amortização de déficits atuariais em fundos de pensão. *Revista Contabilidade & Finanças*, 17(spe2), 09–27. <https://doi.org/10.1590/S1519-70772006000500002>
- Saad, N. S., & Ribeiro, C. O. (2006). Um modelo de gestão de ativo/passivo: aplicação para fundos de benefício definido com ativos de fluxo incerto. *Revista Contabilidade & Finanças*, 17(spe2), 75–87. <https://doi.org/10.1590/s1519-70772006000500006>
- Salotti, B. M., & Carvalho, J. V. F. (2024). On the edge: The impacts of cash flow at risk on the shareholders' equity of public companies in Brazil. *Revista Contabilidade & Finanças*, 35(94). <https://doi.org/10.1590/1808-057x20231907.en>
- Santos, J. G. C., & Coelho, A. C. (2018). Value-relevance of disclosure: risk factors and risk management in Brazilian firms. *Revista Contabilidade & Finanças*, 29(78), 390–404. <https://doi.org/10.1590/1808-057x201806150>
- Seow, R. Y. C. (2024). Determinants of environmental, social, and governance disclosure: A systematic literature review. *Business Strategy and the Environment*, 33(3), 2314–2330. <https://doi.org/10.1002/bse.3604>
- Signorelli, T., Campani, C. H., & Neves, C. (2022). Direct approach to assess risk adjustment under IFRS 17. *Revista Contabilidade & Finanças*, 33(90), 1–15. <https://doi.org/10.1590/1808-057x20221646.en>
- Soares, W. C., & Campani, C. H. (2020). Performance of retirement funds: An analysis focused on pure insurance companies. *Revista Contabilidade & Finanças*, 31(84), 490–523. <https://doi.org/10.1590/1808-057x201909840>
- Souza, F. C. (2019). Upper and lower bounds for annuities and life insurance from incomplete mortality data. *Revista Contabilidade & Finanças*, 30(80), 282–291. <https://doi.org/10.1590/1808-057x201807320>
- Souza, F. C. (2020). Mortality dynamics and the statutory retirement age proposal: an actuarial view. *Revista Contabilidade & Finanças*, 31(82), 165–179. <https://doi.org/10.1590/1808-057x201908250>
- Stadhouders, N., Kruse, F., Tanke, M., Koolman, X., & Jeurissen, P. (2019). Effective healthcare cost-containment policies: A systematic review. *Health Policy*, 123(1), 71–79. <https://doi.org/10.1016/j.healthpol.2018.10.015>

- Stocking, A., Duncan, I., & Huynh, N. (2025). Estimating Underdiagnosis of Patients in Chronically Ill Populations. *North American Actuarial Journal*, 29(1), 1–10. <https://doi.org/10.1080/10920277.2023.2281471>
- Subramanian, A., & Wang, J. (2018). Reinsurance versus securitization of catastrophe risk. *Insurance: Mathematics and Economics*, 82, 55–72. <https://doi.org/10.1016/j.insmatheco.2018.06.006>
- Teixeira, R. F. A. P., Rodrigues, A., & Macedo, M. A. S. (2025). Discretion and assumption choices for closed supplementary pension plans. *Revista Contabilidade & Finanças*, 36(97), e2162. <https://doi.org/10.1590/1808-057x20242162.en>
- Trotta, A. (2024). Environmental impact bonds: review, challenges, and perspectives. *Current Opinion in Environmental Sustainability*, 66, 101396. <https://doi.org/10.1016/j.cosust.2023.101396>
- van de Ven, W., Hamstra, G., van Kleef, R., Reuser, M., & Stam, P. (2023). The goal of risk equalization in regulated competitive health insurance markets. *The European Journal of Health Economics*, 24(1), 111–123. <https://doi.org/10.1007/s10198-022-01457-7>
- van Kleef, R. C., Reuser, M., Stam, P. J. A., & van de Ven, W. P. M. M. (2024). A framework for ex-ante evaluation of the potential effects of risk equalization and risk sharing in health insurance markets with regulated competition. *Health Economics Review*, 14(1), 57. <https://doi.org/10.1186/s13561-024-00540-4>
- Vieira, K. M., Matheis, T. K., & Rosenblum, T. O. A. (2023). Financial preparation for retirement: multidimensional analysis of the perception of Brazilians. *Revista Contabilidade & Finanças*, 34(91), 1–16. <https://doi.org/10.1590/1808-057x20221705.en>
- Wijesena, S., & Pradhan, B. (2025). Advancements in Weather Index Insurance: A Review of Data-Driven Approaches to Design, Pricing and Risk Management. *Earth Systems and Environment*, 9(3), 2355–2379. <https://doi.org/10.1007/s41748-025-00712-0>
- Withagen-Koster, A. A., van Kleef, R. C., & Eijkenaar, F. (2024). High-risk pooling for mitigating risk selection incentives in health insurance markets with sophisticated risk equalization: an application based on health survey information. *BMC Health Services Research*, 24(1), 273. <https://doi.org/10.1186/s12913-024-10774-x>
- Wu, J., Qiao, J., Nicholas, S., Liu, Y., & Maitland, E. (2022). The challenge of healthcare big data to China's commercial health insurance industry: evaluation and recommendations. *BMC Health Services Research*, 22(1), 1–13. <https://doi.org/10.1186/s12913-022-08574-2>
- Zylberstajn, H., Afonso, L. E., & Souza, A. P. (2006). Reforma da previdência social e custo de transição: simulando um Sistema Universal para o Brasil. *Revista Contabilidade & Finanças*, 17(spe2), 56–74. <https://doi.org/10.1590/S1519-70772006000500005>

DATA AVAILABILITY STATEMENT

Not applicable.