

## Article

# Actuarial Risk Management Practices and Firm Performance: The Mediating Role of E-Service Innovation

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**Abstract:** Research on actuarial risk management practices (ARMP) and insurance firm performance has revealed inconsistent results. Therefore, a mediating factor such as innovation is needed to bridge between them. Studies exploring the relationship between ARMP and innovation have been largely qualitative. This study offered a quantitative model focusing on the mediating role of e-service innovation between ARMP and firm performance. The hypothesized relationships were tested using a structural equation model (SEM), with a sample from 98 Indonesian insurance companies and WarpPLS 7.0 as the analytical tool. The results indicated that ARMP significantly influenced e-service innovation but was insignificant for firm performance. Furthermore, the findings highlighted the significant role of e-service innovation in insurance firm performance, which implied that e-service innovation acts as a mediator in the relationship between ARMP and firm performance. The practical application of the research findings makes them directly relevant and beneficial to the insurance industry, especially in Indonesia.

**Keywords:** actuarial risk management practices; e-service innovation; firm performance; insurance industry; Indonesian market



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## 1. Introduction

Product development as part of innovation (Anning-Dorson 2016) is strongly linked to the performance of insurance companies (Rajapathirana and Hui 2018). However, a study by the Society of Actuaries (SOA) team uncovered a paradox (Purushotham et al. 2017). Around 82 percent of survey participants, consisting of top executives from global insurance companies in the U.S. and Canada, claimed that product development is the core competency of their insurance companies. However, only 12 percent of the survey participants reported that their companies had a strong and effective process for creating innovation. The SOA's findings aligned with a study published by R&D World (Panjwani 2019), which showed that U.S. insurance companies engage in fewer innovation activities than other industries.

One of the global crises in 2020—known as the COVID-19 pandemic (WHO 2020), has substantially impacted many sectors of society at all levels (Finsterwalder and Kuppelwieser 2020), including the Indonesian insurance industry (OJK 2020). The pandemic affected the value chain of insurance companies in three critical areas: business operations, underwriting and claims management, and investment management (Liedtke 2021). However, consumers have different views of insurance companies before and during the pandemic. The insurance companies in 2018 were expected to provide fast and efficient services; however, during the pandemic in 2020, insurance companies were expected to create value-for-money products and offer more competitive pricing (Saldanha and Staehle 2020). Moreover, in 2020, 69 percent of consumers (up 19 percent from 2018) would disclose

health or driving data to insurance companies for lower premiums (Saldanha and Staehle 2021). Therefore, insurance companies should be more innovative in price and marketing programs to compete during a crisis.

E-service innovation is one of the substantial driving factors in creating memorable customer experiences (Ciuchita et al. 2019). Especially during the pandemic, customer experience based on technology, automation, and artificial intelligence has become a top priority for top management in various industries, including the insurance industry, as revealed by the results of a global survey by the PwC team (O'Hearn 2020). Business expansion by developing products, distribution, and services based on technology, automation, and analytics is also the primary concern of the leaders of open companies listed on the Indonesian Stock Exchange (including insurance companies) in navigating the service pandemic crisis (Dkstratt 2020). These two studies are reinforced by studies from the McKinsey team (Baig et al. 2020), which show that there has been an acceleration in the adoption of digital channels in various industries (including insurance) due to shifts in consumer behavior triggered by the pandemic. Based on the results of these studies, there is a common thread in e-service innovation.

Insurance regulators from various countries have advised insurance companies to implement several strategic management practices in underwriting, pricing, and claims, known as actuarial risk management practices (Angima et al. 2017), during the pandemic (Yong 2020). These practices, such as adapting product development to crises, expanding coverage, adjusting premium prices flexibly, and prudent solvency management, help meet regulatory compliance and bring significant benefits. They strengthen underwriting management, adopt safer digital product distribution methods, and improve policy services and claims processes, all of which contribute to a more resilient and innovative insurance industry.

Actuarial risk management practices, when implemented effectively, can foster innovation and attract more consumers. For instance, innovative insurance providers that employed novel individual-based risk concepts saw a surge in consumer interest, offering comparable products at a lower premium cost (Cather 2018). In the United States, the life insurance industry demonstrated adaptability by not making price adjustments despite the increase in mortality rates caused by COVID-19 (Harris et al. 2021). This strategic approach allowed insurance companies to adjust premium prices carefully and flexibly based on appropriate risk segmentation, ensuring that customers with low-risk factors were not burdened with increased premium prices. Similarly, the Indonesian life insurance industry also maintained customer trust by not raising premium prices, demonstrating a commitment to ensuring customer coverage (AAJI 2021; Pratama 2021).

Actuarial risk is a distinctive risk exclusive to the insurance industry (Akotey and Abor 2013). This is inherent in underwriting and claims management. Underwriting and claims management play a significant role in the insurance company's value chain, which includes product development, sales and marketing, and asset and risk management (Eling and Lehmann 2018). This study investigates whether the pandemic has impacted the core components of an insurance company's value chain (Liedtke 2021), known as actuarial risk management practices (underwriting, claim, and investment management), and how it might affect firm performance.

Previous studies have investigated the correlation between actuarial risk management practices and insurance firm performance, but few have been conducted in crisis situations (Angima et al. 2017; Felício and Rodrigues 2015). The impact of actuarial risk management practices on firm performance has been inconsistent (Angima et al. 2017), necessitating the inclusion of mediating factors like product and process innovation (Madichie et al. 2013). Many studies that explore the relationship between actuarial risk management practices and innovation are qualitative in nature (Adams et al. 2019; Cather 2018; Syrova 2020). In contrast, this study proposes a quantitative model that rigorously examines the relationship between actuarial risk management practices and e-service innovation. It places particular emphasis on e-service innovation as a crucial mediating factor between

actuarial risk management and firm performance, especially in the face of crises such as the COVID-19 pandemic and other similar situations.

## 2. Theory and Hypotheses

### 2.1. Insurance Firm Performance

While Indonesian insurance penetration may currently be lower than its neighbors, such as Singapore, the Philippines, Thailand, and Malaysia, this presents a significant opportunity for growth (Naujoks et al. 2019). For instance, the ratio of life insurance policies to the Indonesian population is 16.5% (OJK 2022), compared to Singapore's ratio of 268% (MAS 2021), the Philippines 37% (PLIA 2020), Thailand's 38% (Statista 2021), and Malaysia's 39% (LIAM 2020). Based on Global Economy data (GlobalEconomy 2020), Indonesian's premium penetration to gross domestic product is relatively low, only 1.35% for life insurance industry and 0.40% for Property and Casualty (P&C) insurance industry, to compare Singapore (7.01% for life insurance and 0.75% for P&C insurance), Philippines (1.29% for life insurance and 0.55% for P&C insurance), Thailand (3.91% for life insurance and 1.19% for P&C insurance), and Malaysia (2.75% for life insurance and 1.14% for P&C insurance).

Researchers from numerous countries have focused on enhancing insurance firm performance, including Indonesia, which traditionally focuses only on financial aspects (Bahri et al. 2017; Hidayat et al. 2016; Machmud 2016). The financial aspects can be measured by return on investment, return on sales, and profitability (Rajapathirana and Hui 2018). However, improving insurance firm performance is not just about financial perspectives. It can also lead to a more robust and resilient insurance industry that can better meet customer needs and contribute to economic growth. Furthermore, some researchers have discussed how non-financial aspects, such as underwriting risk management, service innovation, and information systems, influence insurance firm performance (Felicio and Rodrigues 2015; Kourtzidis and Tzeremes 2020). The non-financial aspects can be measured by market share, customer satisfaction, new product introduction speediness, and technological competitiveness (Rajapathirana and Hui 2018). Insurance companies can enhance their competitiveness, attract customers, and improve their performance by focusing on financial and non-financial aspects.

### 2.2. E-Service Innovation

Service innovation is innovation in service companies (Miles 1993), including innovation in product development, service processes, pricing, marketing, and service distribution (Anning-Dorson 2016). Moreover, service innovation based on information and communication technology or digital is known as e-service innovation. Service companies utilize service innovation as a differentiation factor to secure market share in routine circumstances (Feng et al. 2020). Nonetheless, the pandemic has significantly influenced the business landscape across all tiers (Finsterwalder and Kuppelwieser 2020). As a result, innovation is a must to maintain customers amidst rapidly evolving market conditions and generate value for clients amidst a crisis (Heinonen and Strandvik 2021). Service innovation is also a strategic reorientation, which is a managerial response to disruptive market challenges (Heinonen and Strandvik 2021).

In developing service innovation during the pandemic crisis, companies need to consider their strategic stretch and horizon. Insurance companies must immediately get out of the turbulent wave of the pandemic (Google et al. 2020) by implementing a "riding out the storm" strategy (Heinonen and Strandvik 2021), which has a short-term strategic horizon with a low strategic stretch. The short-term strategic horizon is the leading choice because these new services modify or adapt existing services to satisfy the new demands without substantially altering the business model or strategy due to the rapid challenges of new modes of interaction and delivery (Heinonen and Strandvik 2021). This strategy was also in line with the direction of the Indonesian Financial Services Authority or OJK indicating that for insurance companies to survive the pandemic crisis, face-to-face sales

methods can immediately utilize digital communication technology due to the physical distancing movement and eliminate the obligation to have wet signatures and replace them with a signature in digital or electronic form (AAJI 2020). At the same time, the choice of low strategic stretch is because the innovation made by insurance companies is slow and conservative (Panjwani 2019). Based on the description, e-service innovation in the insurance industry facing a crisis may include changes in service standards, accelerated service processes, and technology-based service systems (Afifah and Daud 2019; Heng et al. 2020).

### 2.3. Actuarial Risk Management Practices

Insurance companies grapple with a myriad of risks in their day-to-day operations, including actuarial, operational, liquidity, credit, legal, and systematic risks (Akotey and Abor 2013). Actuarial risk, a unique challenge that sets insurance companies apart from other industries, is deeply ingrained in their sales practices (underwriting and pricing management) and obligations tied to insurance policies, such as claims management. Like other financial service companies with risk management functions, insurance companies have specific functions in the company's value chain related to actuarial risk, namely underwriting and claims management (Eling and Lehmann 2018).

Underwriting and pricing management practices focus on standardizing the process, including process automation and product pricing and revision (Angima et al. 2017; Felício and Rodrigues 2015). In addition, claims management practices consist of effective and efficient claims handling (Angima et al. 2017) and robust fraud control (Akomea-Frimpong et al. 2016). Underwriting, pricing, and claims management practices are called actuarial risk management practices (Angima et al. 2017). Actuarial risk management practices in the context of P&C insurance companies in East African countries only impacted non-financial performance, such as customer satisfaction and operational efficiency, and did not affect financial performance, such as profitability and solvency (Angima et al. 2017). However, fraud management practices can positively impact insurance firm performance (Viaene et al. 2007).

The decline of insurance companies' solvency or Risk-Based Capital (RBC) during the pandemic has also been in the spotlight of regulators in various countries (Yong 2020). Risk-Based Capital management is a core of risk management in insurance companies (Eling and Lehmann 2018). Insurance companies must build robust risk management practices, especially when facing a crisis, by preparing sufficient capital and liquidity before a crisis occurs (Richter and Wilson 2020). Moreover, a typical resilient company will prepare for various scenarios and underwriting policy controls in the event of a shock, such as a crisis, that impacts the performance of the company and the functioning of the entire industry (Obrenovic et al. 2020; Richter and Wilson 2020). Therefore, the pandemic's consequences on firms' asset valuation, claims fund reserves, and RBC capital management can be 'risk-migrated,' a term used to describe the distribution or transfer of risks to other entities or sectors. Empirical studies showed that risk management, a form of organizational dynamic capability, can benefit the profits of insurance companies during a crisis (Nair et al. 2014; Shaheen and Ağa 2020).

Moreover, the Jakarta Composite Index (JCI) experienced a significant plummet following the declaration of the global pandemic (IDX 2022). The JCI decrement resulted in a substantial reduction of 19% in investment returns, particularly in the life insurance industry, during 2020 because around 62% of life insurance company assets were allocated to investments in the form of equities and mutual funds on the Indonesia Stock Exchange. Meanwhile, investment returns in the P&C insurance industry declined by around 5%, albeit less significantly than in the life insurance industry, because only about 30% of the assets of general insurance companies were invested in stocks and mutual funds (OJK 2022). To address the challenges posed by unpredictable circumstances, it is imperative for stakeholders in the insurance business, including regulators, investors, and insurance companies, to carefully choose investment methods that reduce risk (Farooq et al. 2021).

These methods could include diversifying investment portfolios, investing in low-risk assets, and regularly reviewing and adjusting investment strategies.

#### 2.4. Conceptual Framework and Development of Hypothesis

Innovations can be a differentiating factor in competitive environments such as the insurance industry. E-service innovation is crucial for insurance companies to survive environmental turbulence. The acceleration of digital transformation drives this due to shifts in consumer behavior that are more digital-minded, triggered by the pandemic crisis. Therefore, service innovation that needs to be performed is related to digital or e-service innovation. Typical practices at insurance companies are required to be more resilient, especially during the pandemic. The increasing risks that insurance companies face are what motivates this. The more robust, fast, and flexible actuarial risk management practices are, the wider the company can creatively build e-service innovation. The relationship between actuarial risk management practices, e-service innovation, and firm performance is presented in Figure 1.

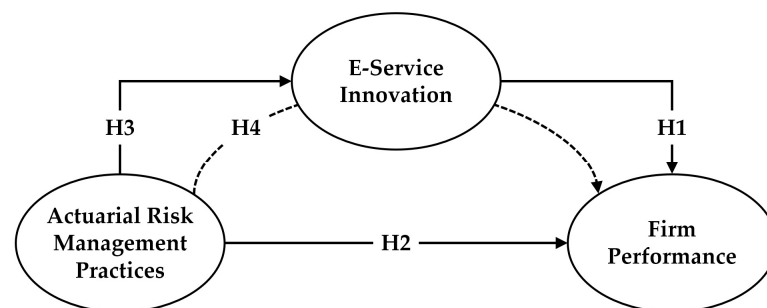


Figure 1. Conceptual model.

Technology-based innovation can be a critical strategic tool for companies to improve competitiveness and performance (Khin and Ho 2019). In general, organizational innovation capabilities influence firm performance (Ho et al. 2018; Huhtala et al. 2014; Wahyono and Hutahayan 2021). In various countries, including Indonesia, widespread empirical evidence exists that service innovation positively impacts firm performance (Afifah and Daud 2019; Heng et al. 2020). More specifically, service innovation affects business performance in insurance companies (Felício and Rodrigues 2015).

Moreover, innovation is needed during a crisis because it can affect company performance. For example, innovation capabilities affected business performance during the 2008 global financial crisis (Huhtala et al. 2014). During the pandemic crisis, innovation capabilities can boost firm performance in Indonesia (Christa et al. 2020; Kristinae et al. 2020). The greater the e-service innovation capability, the better the firm performance. As a result, we suggest the first hypothesis (H1) as follows:

**H1.** *E-service innovation positively influences firm performance.*

Empirical research on general insurance companies in Ghana showed that actuarial risk management practices (underwriting, pricing, and claim management) influenced the company's non-financial performance, such as innovation performance, reputation, and service quality (Angima et al. 2017). However, actuarial risk management practices did not directly affect the financial performance of general insurance companies. On the other hand, testing of panel data of life insurance companies from eight Asian countries showed that underwriting management positively affected company profitability as reflected in return on assets (Zainudin et al. 2018). These results aligned with research on insurance companies (life and P&C insurance) in Portugal and Spain that underwriting management positively affected company performance (Felício and Rodrigues 2015).



Organizations with solid risk management can plan financial contingency measures that help maintain business performance in times of crisis (Obrenovic et al. 2020). For instance, risk management benefited company performance during the global economic crisis of 2008 (Nair et al. 2014). Furthermore, insurance companies are advised to be able to create various analysis scenarios and control underwriting policies as a form of mitigation against the impact of the pandemic on the valuation of company assets and claims fund reserves, as well as capital management (Richter and Wilson 2020). Insurance companies that can carry out proactive risk management through appropriate premium price adjustments due to accelerated COVID-19 mortality based on customer age segmentation can increase business resilience during a pandemic (Carannante et al. 2022). We hypothesize that the stronger the actuarial risk management practices, the better the business performance. As a result, we suggest the second hypothesis (H2) as follows:

**H2.** *Actuarial risk management practices positively influence firm performance.*

In the digital era, risk and innovation are inseparable (da Silva Etges and Cortimiglia 2019; Syrova 2020). Digitized technologies such as artificial intelligence (AI) and machine learning (ML) can enhance risk management efficiency, creating a favorable atmosphere for innovative organizational activities (Syrova 2020). One example is that an effective innovation strategy requires the implementation of a performance management system as part of risk management to keep the implementation of the innovation strategy on track (da Silva Etges and Cortimiglia 2019).

On the other hand, actuarial risk management practices such as underwriting management practices or claims management practices are also closely related to innovative activities in insurance companies. For example, preparing risk classifications for prospective insurers can help reduce selection risk, which is the risk of insuring individuals or entities that are more likely to file a claim in the underwriting process. This can lead to dynamic and individualized product pricing (Cather 2018). In another example, using and utilizing claims data for specific diseases like cancer can drive innovation in healthcare models (Cohen et al. 2019). When developing innovative products during the pandemic crisis, insurance companies must be able to assess the pandemic risk by creating simulations that include predictions of claims due to the pandemic and other sequential events to calculate other potential losses (Qiu 2020). We hypothesize that the more robust actuarial risk management practices, the greater the ability to innovate e-services. As a result, we suggest the third hypothesis (H3) as follows:

**H3.** *Actuarial risk management practices have a positive effect on service innovation.*

Actuarial risk management practices in P&C insurance companies, while demonstrating inconsistent results of influence on firm performance, hold significant potential (Angima et al. 2017). Although these practices may not directly impact the company's financial performance, they have been shown to affect non-financial performance. Based on a qualitative study interviewing top executives of insurance companies in Ghana revealed that these companies managed to increase profits for three years from insurance business operations (referred to as underwriting profit) with an improved risk selection process (underwriting) despite the high-cost pressures of claims (Madichie et al. 2013). This underscores the potential for insurance companies to leverage their dynamic capabilities and realize profit growth targets through product innovation (Madichie et al. 2013).

The primary focus of this research is to understand the link between underwriting performance and product innovation in P&C insurance companies, particularly in the UK context (Adams et al. 2019). The study's results led to two key conclusions. First, the insurance industry is highly competitive and regulated, and insurance companies can only achieve a sustainable competitive advantage by maintaining lower production costs than the market average and optimizing future revenue streams. This can be performed through product and process innovation using new technologies, such as telematics-based

or usage-based premium pricing (Adams et al. 2019). The second conclusion is that risk selection and pricing of risky but profitable products can be economically beneficial for insurance companies (Adams et al. 2019). We hypothesize that the stronger the actuarial risk management practices, the better the business performance through innovation. As a result, we suggest the fourth hypothesis (H4):

**H4.** *Actuarial risk management practices indirectly influence firm performance mediated by e-service innovation.*

### 3. Research Methodology

#### 3.1. Data Collection and Respondent Characteristics

Out of the 138 insurance companies in Indonesia, a rigorous selection process was undertaken. Seven companies, which were experiencing management and operational issues, were purposefully excluded. Additionally, due to the lack of financial performance records predating the COVID-19 crisis for newly established companies, they were also not included. This meticulous approach resulted in a sample size of 98 insurance companies, chosen with a margin of error of 0.05 based on the Krejcie–Morgan formula for a known population (Krejcie and Morgan 1970).

The diversity of Indonesian insurance companies, spanning company type (life and P&C insurance), ownership (state-owned corporation, local private company, and joint venture company), size (total assets), and age (years of operations in Indonesia) necessitated a meticulous approach. We classified the sampling frame based on these characteristics and employed a proportionate stratified sampling method. This method involved selecting a sample from multiple subgroups of the sampling frame (Rahman et al. 2022). The respondents to the survey were top executives at the director level, chief, vice president, or general manager. They filled out a digital questionnaire in Microsoft Forms within the period from March 2022 to September 2022.

Of the 113 insurance companies we contacted, 105 responded and were willing to participate in the questionnaire survey. After they agreed to participate, we sent them the link to the study. To ensure the accuracy of the data, we conducted a thorough verification process using a professional database from LinkedIn and the company website. Some respondents still needed to provide their name and company name. This verification process ensured the correct position level and job function. As a result, the total number of valid samples was 98 insurance companies.

Approximately 42.9% of respondents hold director-level positions, while the remaining 57.1% are at the chief, vice president, or general manager level. The distribution of job functions among the respondents was intentionally diverse, spanning various roles across the insurance company's value chain. These roles encompassed CEO (13.3%); finance and investment (13.3%); operations and information technology (17.3%); sales and distribution (14.3%); product development and marketing (17.3%); actuary and risk management (7.1%), strategy, research, and analytics (12.2%); and legal and compliance (5.1%). This comprehensive representation ensures that the survey findings are unbiased and provide a holistic view of the industry, fostering trust in the results.

The credibility of our survey results is bolstered by the meticulous selection process of the participating companies. A total of 46 life companies and 52 P&C insurance companies, with valid respondents, were included in our study. These companies were selected based on their ownership attributes, with a balanced representation of 4.1% state-owned corporations, 56.1% local private companies, and 39.8% joint venture companies. We also ensured a diverse representation in terms of company size, with 50.0% of big insurance companies (assets of more than USD 345 million for life insurance companies and USD 69 million for P&C insurance companies) and 50.0% of small–medium insurance companies. In terms of company age, 71.4% of the participants have more than 20 years of operating in Indonesia, and 28.6% have equal to or less than 20 years of business in Indonesia. This careful selection

of participants ensures that our survey results are accurate and reliable, representing the Indonesian insurance industry.

### 3.2. Measurement of Variables

This study utilized adapted indicators, making some modifications to align business processes in the insurance industry, such as variable actuarial risk management practices (Angima et al. 2017; Farooq et al. 2021; Richter and Wilson 2020), e-service innovation (Afifah and Daud 2019; Heng et al. 2020), and insurance firm performance (Felício and Rodrigues 2015; Krashennnikova et al. 2019; Rajapathirana and Hui 2018). Before we conducted a complete survey, we had several iterative sessions to validate logical or content questionnaires (Sekaran and Bougie 2016) with experts from the insurance industry. This survey questionnaire uses an ordinal Likert scale with six options that have gradations from strongly disagree to strongly agree to avoid central tendencies in the answers when filling out the questionnaire (Sekaran and Bougie 2016). The questionnaire is also equipped with questions about demographic data as a control and descriptive data that describes the company's situation. The default questionnaires were in Indonesian, but we also provided an English version to cover 28 indicators. The questionnaire asked about the improvement in indicator conditions (more significant results or more frequent activity) when the survey was conducted during the pandemic compared to before the crisis. These findings provide crucial insights into the impact of the pandemic on various business processes in the insurance industry, offering a valuable resource for industry professionals.

As an alternative to the Covariance-based Structural Equation Modeling (CB-SEM) technique, a significant number of researchers employ the Partial Least Squares Structural Equation Modeling (PLS-SEM) methodology (Hair et al. 2014). PLS-SEM is carried out to establish the validity of conceptual models in business and management research. In circumstances where the study will be based on exploratory and incorporates formative constructs, PLS-SEM is a valuable choice for analysis (Hair et al. 2014). Because this study was an exploratory investigation, the PLS-SEM methodology utilized in this investigation was the software built by Warp-PLS 7.0.

## 4. Results and Discussion

### 4.1. Results

In Table 1, some indicators from the variable of actuarial risk management practices were dropped due to factor loading values below the threshold of 0.6. Furthermore, Table 1 showed that the variables' constructs fulfilled the thresholds of 0.50 of AVE (Average Variance Extracted), a minimum of 0.60 of Cronbach's Alpha, and a minimum of 0.70 of CR (Composite Reliability) (Hair et al. 2014). Therefore, all variables were reliable for this study.

**Table 1.** Reliability test.

Variable	Construct	Indicator	Factor Loading	Cronbach's Alpha	CR	AVE
Actuarial Risk Management Practices (ARMP)	Underwriting and Pricing Management Practice	AI in underwriting process	0.874	0.689	0.866	0.763
		Speediness underwriting process	drop			
		Advanced analytics in pricing model	0.874			
		Regular revamp for pricing	drop			
	Claim Management Practice	Instant claim process	0.766	0.633	0.803	0.577
		Effective claim management	0.773			
		Minimized claim litigation	0.738			
		Analytics in fraud detection	drop			
	Risk Management Practice	Business Continuity Plans	drop	0.890	0.948	0.901
		Investment management	0.949			
		Solvability management	0.949			



Table 1. Cont.

Variable	Construct	Indicator	Factor Loading	Cronbach's Alpha	CR	AVE
E-Service Innovation (ESI)	Service Standard Changes	New approach marketing program	0.896	0.700	0.835	0.632
		New business model exploration	0.820			
		New product/services benchmark	0.648			
	Accelerated Service Process	Unique benefits for services	0.760	0.705	0.836	0.630
		Complaint resolution speediness	0.793			
		New method business process management	0.826			
	Technology-based service system	Digital sales channel	0.850	0.817	0.891	0.732
		Digital payment method	0.856			
		Digital contact service	0.861			
	Firm Performance (FP)	Financial Performance	Premium income	0.874	0.901	0.931
Premium growth			0.922			
Return on investment			0.862			
Profitability			0.855			
Non-Financial Performance		Market share	0.774	0.751	0.843	0.576
		Customer satisfaction	0.762			
		Speediness product launch	0.832			
		Technological competitiveness	0.655			

Source: processed data from WarpPLS 7.0 (validity criteria fulfilled with the loading value  $\geq 0.6$ ).

A test of discriminant validity is shown in Table 2. By the findings of the Fornell–Lacker criterion, the connection between variables and the square root of AVE suggested that there was no issue with the numerical values at the top being the most significant. Based on Table 2, all variables were valid.

Table 2. Discriminant validity test.

	FP	ESI	ARMP
FP	0.872		
ESI	0.478	0.827	
ARMP	0.151	0.523	0.671

Source: processed data from WarpPLS 7.0.

Based on the output of WarpPLS 7.0, Table 3 showed that this research model had Goodness of Fit (GoF) with R-squared (determination coefficient) and Q-squared (predictive relevance indices) (Hair et al. 2014; Sholihin and Ratmono 2020). The R-squared of e-service innovation (ESI) was 0.274 with 0.274 of effect size from actuarial risk management practices (ARMP). The Q-squared of ESI was 0.274, which means its exogenous variable had medium power as a predictor. Meanwhile, the R-squared of firm performance (FP) was 0.268 with 0.255 of effect size from ESI and 0.013 from ARMP. Meanwhile, the Q-squared of FP was 0.243, which means the predictive relevance from its predictor variables is medium power.

Table 3. R-squared, Q-squared, and effect size.

Item	ESI	FP
R <sup>2</sup>	0.274	0.268
Q <sup>2</sup>	0.274	0.243
Effect size of ESI	-	0.255
Effect size of ARMP	0.274	0.013

Source: processed data from WarpPLS 7.0.

Table 4 presents the outcome of WarpPLS 7.0, which was used to ensure that the research model used in this study was as optimized as possible by using PLS-SEM Model Fit and Quality Indices. Every single index in Table 4 was a good fit for the requirements, making this research model acceptable.

**Table 4.** Model Fit and Quality Indices.

Model Fit and Quality Indices	Assessment	Fit Criteria	Note
Average path coefficient (APC)	0.375, $p < 0.001$	$p < 0.05$	Good
Average R-squared (ARS)	0.271, $p < 0.001$	$p < 0.05$	Good
Average adjusted R-squared (AARS)	0.259, $p < 0.001$	$p < 0.05$	Good
Average block VIF (AVIF)	1.274	acceptable if $\leq 5$ , ideally $\leq 3.3$	Ideal
Tenenhaus GoF (GoF)	0.429	small $\geq 0.1$ , medium $\geq 0.25$ , large $\geq 0.36$	Large
Sympson's paradox ratio (SPR)	1.000	acceptable if $\geq 0.7$ , ideally = 1	Ideal
R-squared contribution ratio (RSCR)	1.000	acceptable if $\geq 0.9$ , ideally = 1	Ideal
Statistical suppression ratio (SSR)	1.000	acceptable if $\geq 0.7$	Acceptable
Nonlinear bivariate causality direction ratio (NLBCDR)	1.000	acceptable if $\geq 0.7$	Acceptable

Source: processed data from WarpPLS 7.0.

In Table 5, all hypotheses were significant except H2, which was the hypothesis test on the direct relationship between actuarial risk management practices (ARMP) and firm performance (FP). For the indirect relationship, hypothesis H4 was accepted. Furthermore, the mediator type can be classified based on Variance Accounted For (VAF) with  $VAF = \text{Indirect Effect} / \text{Total Effect}$  (Hair et al. 2014). Based on WarpPLS 7.0 output (see Table 5), the total effect of actuarial risk management practices on firm performance was 0.353 (0.079 direct effect plus 0.274 indirect effect). Therefore, VAF was 0.776, and e-service innovation can act as a partial mediator. However, the relationship between actuarial risk management practices and firm performance (stated as H2) was rejected; then, e-service innovation (ESI) became the full mediator between actuarial risk management practices (ARMP) and firm performance (FP).

**Table 5.** Standardized path coefficients for general model.

Hypotheses	Path Link	Path Coefficient ( $\beta$ )	$p$ -Values	Result
H1	ESI $\rightarrow$ FP	0.523	$<0.001$	Significant
H2	ARMP $\rightarrow$ FP	0.079	0.193	Not significant
H3	ARMP $\rightarrow$ ESI	0.523	$<0.001$	Significant
H4	ARMP $\rightarrow$ ESI $\rightarrow$ FP	0.274	$<0.001$	Significant

Source: processed data from WarpPLS 7.0.

#### 4.2. Discussion

The study's findings, which underscore the crucial role of e-service innovation on firm performance during a crisis, such as the COVID-19 pandemic, significantly contribute to the existing research. These findings show how service innovation can affect business performance in the insurance industry, even before the COVID-19 pandemic (Felício and Rodrigues 2015). Moreover, the need for innovation during a crisis is highlighted, as it can positively affect firm performance (Huhtala et al. 2014), as evidenced by the COVID-19 pandemic crisis in the non-insurance sector in Indonesia (Christa et al. 2020; Kristinae et al. 2020). Referring to Table 1, the dimension with the highest index in the variable e-service innovation, as presented by Cronbach's Alpha, is a technology-based service system comprising a digital sales channel, digital payment, and digital contact service. These channels are crucial in the current scenario, where customer behaviors have shifted due to the pandemic (Baig et al. 2020). This outcome reaffirms previous arguments (Heng et al.

2020) and introduces a perspective on how service innovation impacts firm performance in the insurance industry, both pre- and post-pandemic, thereby providing valuable insights for industry professionals and policymakers.

The findings from our study, based on a sample of Indonesian insurance companies during the pandemic, supported the argument of previous research that actuarial risk management practices, including underwriting, pricing, and claims management, have no direct impact on the financial performance of insurance companies (Angima et al. 2017). This study also aligns with studies that suggest claim management, as reflected in the loss ratio and net claim, does not directly influence firm performance, such as profitability (Emmanuel and Goodwill 2018). Furthermore, this study supports the notion that there is no significant correlation between solvency management and insurance firm performance, such as return on assets and investment income ratio (Alokla et al. 2023).

However, actuarial risk management practices have a positive impact on e-service innovation. This finding is robustly supported by empirical evidence. This research provides quantitative backing to qualitative studies demonstrating how properly segmenting individual risks in the underwriting process can drive dynamic product pricing as an innovative solution that does not generalize risk for all customers (Cather 2018). Furthermore, the empirical results of this study are fortified by qualitative research during the pandemic, which highlights the necessity for insurance companies to create simulation models that include COVID-19 claims and other potential losses related to pandemic events in innovative solutions to anticipate more significant potential losses (Qiu 2020).

Crucially, actuarial risk management practices can influence insurance firm performance by mediating e-service innovation during the pandemic. This finding provides concrete empirical evidence that insurance companies can enhance profitability by leveraging the underwriting process and utilizing dynamic organizational capabilities, specifically product innovation (Madichie et al. 2013). Furthermore, this study's findings also fortify the argument for risk selection (underwriting) and pricing strategies for risky but profitable products that can provide economic benefits through product and process innovations using new technology (Adams et al. 2019).

## 5. Conclusions

Insurance companies must develop innovative services to survive environmental instability. Pandemic-induced consumer changes toward digital are speeding digital transformation. The needed service innovation is digital or technological. Insurance operations must be more resilient, especially during pandemics. The increased risks insurance firms face drive this. The company can create e-service innovation with more robust, fast, and flexible actuarial risk management approaches. This study analyzed how e-service innovation affects actuarial risk management and firm performance.

The results of hypothesis testing confirm that actuarial risk management practices significantly influence e-service innovation, a form of digital-based innovation that enhances the efficiency and effectiveness of insurance services, whereas they display insignificant effects regarding insurance firm performance. This could be due to the complex and multifaceted nature of insurance firm performance, which may be influenced by a wide range of factors beyond actuarial risk management practices. Furthermore, e-service innovation significantly contributes to firm performance. Therefore, e-service innovation mediated the relationship between actuarial risk management practices and firm performance.

This study guided the development of innovation strategies that insurance companies should adopt in crises such as the COVID-19 pandemic or the new era after the pandemic. The innovation that needs to be developed is digital-based innovation, called e-service innovation. The development of e-service innovation also needs to consider other elements, such as strengthening actuarial risk management practices. This research, by providing a comprehensive understanding of the interplay between actuarial risk management practices, e-service innovation, and firm performance, offers a unique perspective that can significantly contribute to the resilience and adaptability of insurance companies in cri-

sis situations. Thus, the results of this study, especially the research indicators, can be a detailed technical guide in implementing e-service innovation in Indonesian insurance companies to address crises.

While the data sample is from the Indonesian insurance market, the research methodology has universal applicability because most insurance markets face similar challenges when confronting a pandemic crisis. They should adapt product development to crises, adjust premium prices flexibly, strengthen underwriting management, adopt digital distribution, and improve policy services and claims processes (Yong 2020). These practices involve actuarial risk management practices and service innovation, making the research relevant and applicable to various contexts.

It is essential to acknowledge the limitations of this study, as it is a tested conceptual framework based on a cross-section survey. Data collection for this study was only conducted in one period, when COVID-19 was still declared a pandemic. The suggestion for future research is to continue this study with a data collection period of about 3–4 years after this research launch with the same respondents and insurance companies to see the sustainability of the impact of the research variables. Hence, conducting longitudinal research can provide an opportunity to empirically validate the hypothesis developed in this work, considering the rapid evolution of consumer preferences and technology. This transparency enhances the credibility of the research.

The development of technology and digital-based service innovation should be a top priority for insurance companies. This is because, as evidenced by studies from global companies (O'Hearn 2020) and public companies listed on the Indonesian Stock Exchange during the pandemic crisis (Dkstratt 2020), these companies were able to enhance their daily operations and develop services for customers by applying automation, analytics, and artificial intelligence technology. These digital technologies include improved efficiency, enhanced customer experience, and increased competitiveness. This research only summarizes actuarial risk management practices as factors that influence e-service innovation. Further study development is to test digital variables in developing e-service innovation, especially in the financial services industry, such as insurance.

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