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DOES FINANCIAL INNOVATION SUPPORT DEVELOPMENT OF PENSIONS AND INSURANCE? THE MODERATING ROLE OF GREEN TECHNOLOGY

Nafis Dwi Kartiko[1],
M. Silahul Mu'min[2],
Muhammad Syariful Anam[3]

ABSTRACT

This study aims to assess the impact of financial innovation on the development of pension and insurance systems in ASEAN countries. Using secondary data analysis methods from 10 ASEAN member countries over the period 2004-2021, this study found that financial innovation has a positive and significant influence on operational efficiency and risk management in both sectors. The adoption of new financial technologies and innovative strategies is proven to promote sustainable growth, as well as strengthen financial stability, which has a positive impact on the welfare of people who depend on pension and insurance services. In addition, the application of green technologies in pension and insurance fund management also supports environmental sustainability and generates positive economic impacts. These findings confirm the importance of policies that support financial innovation as a key strategy in strengthening financial systems in the ASEAN region.

Keywords :
Financial Innovation, Pension, Insurance Industry

JEL Classification : G21, G22, J32

[1]Directorate General of Taxes, Ministry of Finance of the Republic of Indonesia
nafisdwikartiko@gmail.com
[2]Universitas Diponegoro, Semarang, Indonesia
msilahulm@gmail.com
[3]Universitas Diponegoro, Semarang, Indonesia
syarifulanam2700@gmail.com

I. Introduction

Financial innovation has been a pivotal factor in the advancement of the financial sector, as it introduces novel products, processes, and technologies that enhance efficiency, profitability, and overall performance. The findings of the research conducted by Nazir et al. (2020) indicate that financial innovation has a positive impact on economic growth. This is achieved through the promotion of capital expansion, industrial progress, and the development of new technologies. Moreover, these innovations are inextricably linked to the advancement of the financial sector, as elucidated by Qamruzzaman & Jiang (2019). They lead to enhanced financial services, banking efficiency, and financial inclusion. Furthermore, there is a positive correlation between financial innovation and higher bank profitability, which is a crucial factor for the long-term sustainability and expansion of financial institutions, as outlined by Mustansar (2023).

The advent of fintech, a term denoting the confluence of technology and innovation, has precipitated a profound transformation in the financial sector, with the advent of sophisticated services in banking, investment, and insurance (Yadav, 2023). Fintech initiatives are regarded as significant breakthroughs that facilitate transformation in the financial sector, as asserted by Karthika et al. (2022). Furthermore, the advent of Fintech has also given rise to the development of branchless banking models, which enhance the performance of banking institutions by facilitating innovative service delivery (Chipeta & Muthinja, 2018). Financial innovation is not merely the introduction of new products; it also encompasses the enhancement of governance frameworks and legal structures, thereby facilitating the adoption of innovative financial and fiscal practices in digitised settings (Dmytryk et al., 2022). The digital economy plays a pivotal role in propelling innovation in retail finance, with its capacity to foster industry integration, refine regulatory systems and harness digital technologies to enhance financial services.

In addition to banking, businesses with a significant role in the financial sector include pension funds and insurance. Pension funds and

insurance play a pivotal role in the financial industry, functioning as institutional investors and financial intermediaries. These institutions exert a considerable influence on the development of the stock market, the deepening of the financial system, and the expansion of the economy. The asset allocation strategies of pension funds and insurance companies exert a considerable influence on stock market dynamics, as elucidated by (Bayar et al., 2022). Pension funds play an instrumental role in fostering economic growth by directing contributions into long-term investments, which in turn reinforce the national economy (Kasri et al., 2020). Furthermore, pension funds play a pivotal role in financialisation activities, underscoring their substantial influence within the financial sector (Zwan & Golka, 2023).

The extant literature demonstrates that pension funds and insurance have a positive impact on financial development. The presence of a well-developed pension fund industry is associated with economic growth, financial system stability, and the effective allocation of funds to various economic sectors (Abdul, 2023; Kasri et al., 2017). Moreover, these funds act as strategic investors, thereby reinforcing financial system stability and accelerating stock market growth in economies undergoing a transition (Кузнецова & Pisarenko, 2019). Pension funds and other institutional investors play a pivotal role in maintaining market liquidity, activity, and financial stability (Krišto et al., 2014). Furthermore, they contribute to the management of financial sector risk, with regulators focusing on financial risk management in this sector due to its pivotal role in financial markets (Yang & Tapadar, 2014). Pension funds also play a significant role in investing in economic growth, but their strengthening can pose a danger to financial stability (Kolodiziev et al., 2021). By allocating assets to infrastructure projects and long-term investments, such as green energy-focused initiatives, insurance companies and pension funds play a role in supporting sustainable financing and development (Taghizadeh–Hesary & Yoshino, 2020).

The aim of this study is to examine the impact of financial innovation on the evolution of pension and insurance systems in ASEAN countries. Financial innovation plays an important role in the evolution of insurance

and pension systems, as evidenced by the findings of Bonizzi & Churchill (2017). These authors posit that pension funds are a vital catalyst for financial growth and innovation, driving the demand for bespoke financial assets. This has implications not only for the creation of financial products but also for the wider financial industry. Moreover, this research will examine the impact of foreign direct investment (FDI) on the export of financial and insurance services, including pension services. This will emphasise the importance of global transactions in stimulating innovation and expansion in the insurance and pension industries (Kaya et al., 2022). The relationship between pension and insurance funds and financial depth has been examined under various conditions, demonstrating that these funds play a pivotal role in enhancing the financial environment in diverse countries (Abdul, 2023). The insurance market has also been shown to have a positive effect on economic growth, which highlights the relationship between the development of the insurance industry and economic prosperity (Baruti, 2020). It is increasingly acknowledged that institutional investors, including pension funds and insurance companies, play a pivotal role in maintaining financial market stability. The investment strategies and long-term funding mechanisms employed by these organisations enhance financial market stability, thereby emphasising their importance within the wider financial ecosystem (Krišto et al., 2014). The inclusion of contributory pension systems has resulted in a significant expansion of the financial industry, with pension funds assuming a prominent role in bond and stock market capitalisation (Odo & Chinedu, 2016).

This research makes a novel contribution to the field by integrating the moderating effect of green technology in investigating the innovation relationship of pension and insurance funds. The integration of green technology offers a variety of techniques that can facilitate the advancement of these financial institutions, particularly through green financing and investment in renewable energy projects. As posited by Taghizadeh–Hesary & Yoshino (2020), government financial institutions and non-banking financial institutions, including pension funds and insurance companies, have significant potential to contribute to the advancement of green technologies through this approach. Furthermore, the implementation of green credit guarantee programmes can mitigate

the credit risk associated with green projects, thereby enhancing their appeal as investment opportunities.

This study makes a significant contribution in both the theoretical and practical realms towards understanding the influence of financial innovation on pension funds and insurance industries in ASEAN countries. Theoretically, this study extends the existing literature framework by integrating the role of green technology as a moderating factor in the relationship between financial innovation and financial institution development. This broadens the understanding of how green policies and technologies can interact with the financial sector to accelerate the development of the pension fund and insurance industry. Practically, the results of this study can serve as a reference for policy makers and practitioners in the financial sector to formulate effective strategies in implementing green technology. In addition, the results of this study also have the potential to provide a basis for financial institutions to design products and services that support the transition towards more sustainable and environmentally friendly operations, in accordance with global trends and market demands.

II. Literature Review

A. The Impact of Financial Innovation on Development of Pensions and Insurance

In the context of financial sector development, financial innovation is of critical importance in advancing economic performance and generating new economic prospects. A study conducted by Bara & Mudzingiri (2016) demonstrated that financial innovation plays a pivotal role in propelling economic growth through the generation of novel economic initiatives. This entails the incorporation of technology and novel concepts into financial services, thereby enhancing the quality of service delivery in sectors such as banking, investment, and insurance (Yadav, 2023). Liu (2022) demonstrated that financial innovation can enhance the financial performance of banks. The impact of firm-specific characteristics on current financial performance is more pronounced than that of factors

pertaining to the sector as a whole. Moreover, Khan et al. (2021) have demonstrated that financial innovation is a significant driver of long-term economic growth and an effective means of mitigating credit risk in the banking sector. Omollo et al. (2022) have identified diversification of financial services as a pivotal factor in supporting financial progress, technical advancement, enhanced market access, and overall economic expansion.

According to Amjad et al. (2023), the interaction between risk management and financial innovation has a positive impact on bank efficiency and profitability. Meanwhile, Dayi (2020) found that the introduction of financial innovation procedures in the banking industry has increased the level of financial achievement. Abaidoo (2023) emphasised the importance of effectively managing regulatory policy uncertainty to ensure that innovation in the banking industry has a beneficial impact on financial sector development in emerging markets. In conclusion, financial innovation is an important catalyst that not only supports the growth of the financial industry but also succeeds in enhancing overall economic success by increasing competitiveness, better service delivery, and improved financial performance.

Financial innovation is a crucial element in the pension fund and insurance business, as it serves to stimulate growth and address the evolving needs of these financial institutions. Pension funds are acknowledged for their role in promoting financial innovation through the generation of demand for suitable financial assets (Bonizzi & Churchill, 2017). The growing necessity for pension disbursement has led to the development of automated systems, which illustrate the integration of technology in the administration of pension funds (Chauhan, 2024). Furthermore, pension funds have been associated with the integration of financial markets, leading to the implementation of a market-based approach to the governance of old-age security (Schelkle, 2019). The relationship between pension funds, financial innovation and economic growth is a topic that has been extensively researched.

The deployment of pension fund assets has been identified as a key driver of financial performance and the fulfilment of the need for financial innovation (Kolodiziev et al., 2021). Furthermore, the integration of Environmental, Social, and Governance (ESG) principles into the governance of pension funds is regarded as a significant step towards a financially sustainable and ethically sound future for beneficiaries (Ikwue, 2023). The impact of financial market crises has also affected the susceptibility of pension funds, necessitating the implementation of efficient governance and risk management techniques (Wiß, 2014). The increasing lifespan of individuals is altering the financial equilibrium of pension funds, underscoring the significance of adjusting to evolving patterns in life expectancy. Furthermore, the administration and oversight of pension funds are of paramount importance in guaranteeing the monetary security of plan participants and the overall welfare of the nation. In conclusion, financial innovation in the pension fund and insurance sector is essential for driving growth, meeting the needs of beneficiaries, and ensuring the long-term sustainability of these financial entities. In light of the preceding literature, the research hypothesis is formulated as follows:

H_1: Financial innovation has a significant positive impact on pension fund development.

H_2: Financial innovation has a significant positive impact on the development of the insurance industry.

B. The Moderating Green Technology Impact of Financial Innovation on Development on Pensions and Insurance

The pension fund sector and the insurance industry are undergoing a gradual transformation as a result of the increasing influence of green technology, which is affecting investment decisions and shaping sustainability policies. Pension funds, as institutional investors, are being encouraged by socially responsible funds to adopt ecologically sustainable activities (Alda, 2019). There is an increasing desire to utilise pension fund assets to support environmentally friendly improvements, which may necessitate adjustments to investment strategies and financial institutions (Berg, 2021). Pension funds are receiving increased recognition for their

contribution to combating climate change, particularly in the context of the gradual elimination of fossil fuels (McDonnell, 2024). In order to achieve this, it may be necessary for pension funds to undergo a significant transformation in their roles and methods. Technological solutions are playing an increasingly vital role in the management of pension funds, with researchers investigating the potential for automated distribution of pension payments by 2024. Furthermore, green finance activities are enhancing ecological resilience by prioritising information transparency, environmental oversight, and the implementation of green credit evaluation systems (Le, 2024). The integration of environmental, social, and governance (ESG) principles into the governance and management of pension funds represents a significant shift towards a financially sustainable future (Ikwue, 2023).

Pension funds that integrate sustainable development into their strategic framework can achieve a harmonious equilibrium between financial success and social responsibility (Sievänen et al., 2017). Furthermore, sustainable energy sources and clean technologies, which are regarded as green projects, require a diverse range of funding channels. This underscores the pivotal role of pension funds in providing financial backing for initiatives aimed at fostering green growth (Croce et al., 2011). It is posited that green insurance and technology insurance act as catalysts for corporate green innovation in the insurance business (Pu, 2024). Insurance firms and pension funds are increasingly providing financial support for extensive green energy initiatives, such as hydropower, due to the enduring characteristics of such projects (Taghizadeh–Hesary & Yoshino, 2020). The green insurance market is undergoing significant changes, with a particular focus on legislative frameworks, technological advancements, and talent development to encourage sustainable growth (Lee, 2023). In light of the preceding literature, the research hypothesis is formulated as follows:

H_{3a}: Green technology moderates the positive effect of financial innovation on pension fund development.

H_{3b}: Green technology moderates the positive effect of financial innovation on the development of the insurance industry.

III. Data and Method

A. Data and Samples

In this study, the method used is secondary data analysis by investigating 10 ASEAN member countries, namely Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam, Brunei Darussalam, Cambodia, and Indonesia. The time span selected for analysis is from 2004 to 2021. The data used in this study was obtained from three main sources: World Development Indicators, Global Financial Development, and Environment Social and Governance (ESG) Data, all provided by the World Bank.

B. Operationalisation of Research Variables

The operationalisation of the variables in this study is presented below (Table 1).

Table 1. Operationalisation of Variables

Variable	Operationalisation
Moderating Variable	
Green Technology **(GRETECH)**	The Green Technology (GRETECH) variable in this study measures the application and impact of green technology in various economic sectors using principal component analysis (PCA). This method is adapted from (Elgin et al., 2023; Li et al., 2024; Luo & Liang, 2016). This variable includes various indicators that reflect the use of clean technology and socio-economic responsibility in business practices and daily life. The first indicator is access to clean fuels and technologies for cooking, which is measured for the population as a whole, as well as separately for rural and urban populations. This gives an idea of how widespread the deployment of clean technologies is in cooking, which is an important aspect of daily life. Furthermore, this variable also considers how much firms identify access to finance as a key constraint, as well as the percentage of firms that use banks to finance investments. These two indicators show the

Variable	Operationalisation
	extent to which the financial sector supports sustainable and responsible investment. Additionally, this variable includes CO2 emissions per capita, which is a direct indicator of the environmental impact of a country's economic activity. The final indicator in the PCA analysis is the Economic and Social Rights Performance Score, which provides a comprehensive evaluation of how well a country implements policies that support sustainable development and the socioeconomic rights of its citizens.
Independent Variable	
Financial Innovation **(FINNOV)**	The Financial Innovation (FINNOV) variable in this study is measured using principal component analysis (PCA) of several indicators that indicate the level of financial innovation in a country's economy. This variable includes the number of Automated Teller Machines (ATMs) per 100,000 adults, which indicates the ease of access to electronic banking services. In addition, the percentage of individuals using the internet is calculated to illustrate how widespread the use of digital technology is in the population. Also included is the percentage of high-tech exports out of total manufacturing exports, which signifies the level of technology adoption and development in the production sector. Additional variables such as the percentage of the population aged 15 years and above who own credit and debit cards provide insights into financial inclusion and the adoption of modern means of payment. The variable also includes the number of patent applications by non-residents and residents, reflecting innovation activity in the economy. The use of the PCA method allows combining these indicators into a single index that is effective for analysing the impact of financial innovation, in accordance with the methodology adopted from studies by (Jungo et al., 2024; Qamruzzaman & Jiang, 2019; Qamruzzaman & Jianguo, 2017).
Dependent Variables	
Pension fund assets to GDP (%) **(PENSION)**	This variable measures the proportion of pension fund assets to a country's Gross Domestic

Variable	Operationalisation
	Product (GDP). This ratio gives an indication of the importance of pension funds in the national economy, reflecting how much pension fund investment activity is relative to total economic output.
Insurance company assets to GDP (%) **(INSURANCE)**	This variable measures the proportion of insurance company assets to a country's GDP. This ratio illustrates the financial significance of insurance companies in the economy, showing how much of a role insurance companies play in stabilising and supporting economic activity through risk management and savings mobilisation.
Life insurance premium volume to GDP (%) **(LIFEINS)**	This variable measures the proportion of total life insurance premiums paid relative to GDP. This ratio assesses the importance of life insurance in the economy, indicating the level of life insurance penetration and how much people allocate their income for long-term protection.
Non-life insurance premium volume to GDP (%) **(NONLIFEINS)**	This variable measures the proportion of total non-life insurance premiums paid to GDP. This ratio reflects how influential non-life insurance is in the economy, which includes vehicle, property, and other insurance, giving an idea of people's tendency to protect their assets and business activities from various risks.
Control Variables	
Bank Z-score **(ZSCORE)**	Bank Z-score is a metric used to assess the stability of a country's commercial banking system by measuring the probability of failure. The score compares the buffers of the commercial banking system, which consist of capitalisation and returns, with the volatility of those returns. As such, the Bank Z-score provides a snapshot of a bank's financial safety in the face of market fluctuations, making it an important indicator in financial risk analysis.
Bank return on assets (%, after tax) **(ROA)**	The Return on Assets (ROA) variable is a measure of the financial efficiency of a country's banking companies. ROA is calculated by dividing a commercial bank's net income after tax by its annual average total assets. This ratio illustrates the bank's ability to generate profit from its

Variable	Operationalisation
	assets, providing an important indicator of the bank's financial performance.
Bank return on equity (%, after tax) **(ROE)**	The Return on Equity (ROE) variable is defined as a ratio that measures the financial performance of commercial banks. ROE is calculated by dividing net income after tax by annual average equity. This ratio provides an overview of how effectively a commercial bank manages its equity to generate profits, making it an important indicator to assess management efficiency in generating value for shareholders.
Bank non-performing loans to gross loans (%) **(NPL)**	The Non-Performing Loans (NPL) variable is defined as the percentage of non-performing loans out of the bank's total gross loans. NPL measures the proportion of loans that fail to fulfil their obligations according to a predetermined schedule, providing an indicator of the credit risk faced by the bank. This ratio is important in assessing the quality of bank assets and the effectiveness of credit risk management applied by financial institutions.

C. Econometric Model

The approach used in this study is Ordinary Least Squares (OLS). The following is the regression model used to determine the impact of financial innovation on development of pensions and insurance with green technology as moderating variable:

$$
\begin{aligned}
PENSION_{i,d} &= \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 \varphi_{i,d} + \epsilon \\
INSURANCE_{i,d} &= \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 \varphi_{i,d} + \epsilon \\
LIFEINS_{i,d} &= \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 \varphi_{i,d} + \epsilon \\
NONLIFEINS_{i,d} &= \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 \varphi_{i,d} + \epsilon \\
PENSION_{i,d} &= \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 GRETECH_{i,d} + \beta_3 (GRETECH \times FINNOV)_{i,d} \\
&\quad + \beta_4 \varphi_{i,d} + \epsilon \\
INSURANCE_{i,d} &= \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 GRETECH_{i,d} + \beta_3 (GRETECH \times FINNOV)_{i,d} \\
&\quad + \beta_4 \varphi_{i,d} + \epsilon \\
LIFEINS_{i,d} &= \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 GRETECH_{i,d} + \beta_3 (GRETECH \times FINNOV)_{i,d} \\
&\quad + \beta_4 \varphi_{i,d} + \epsilon \\
NONLIFEINS_{i,d} &= \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 GRETECH_{i,d} + \beta_3 (GRETECH \times FINNOV)_{i,d} \\
&\quad + \beta_4 \varphi_{i,d} + \epsilon
\end{aligned}
\tag{1}
$$

The dependent variables in this study are pension fund assets to GDP (PENSION), insurance company assets to GDP (INSURANCE), life insurance premium volume to GDP (LIFEINS), and non-life insurance premium volume to GDP (NONLIFEINS). The independent variable in this study is Financial Innovation (FINNOV), while the moderating variable is Green Technology (GRETECH). The variable $\varphi_{i,d}$ is a control variable consisting of Bank Z-score (ZSCORE), Bank Return on Assets (ROA), Bank Return on Equity (ROE), and Bank Non-Performing Loans (NPL).

IV. Result and Discussion

A. Descriptive Statistics and Correlation Coefficient

The present study employs descriptive statistical analysis to delineate the attributes of the data set, encompassing the primary variables (summarised in Table 2). The measurement of each variable is based on the number of observations, mean, standard deviation (SD), minimum value (min), and maximum value (max). To illustrate, the PENSION variable, which reflects pension fund assets relative to gross domestic product (GDP), exhibited a mean of 7.714 with a standard deviation of 15.9, a minimum value of 0, and a maximum of 61.214, out of a total of 180 observations. A similar pattern is evident in the INSURANCE variable, which indicates the mean assets of insurance companies relative to GDP, amounting to 9.942 with a standard deviation of 12.908. Other variables, such as LIFEINS and NONLIFEINS, demonstrate the penetration of life and non-life insurance premiums to GDP, respectively. The variables FINNOV and GRETECH, which respectively measure financial innovation and the influence of green technology, both display data distributions characterised by mean values, standard deviations, and minimum and maximum values that provide insight into the distribution of data within the sample. In the context of ZSCORE, this variable provides insight into the stability of the banking system, with a mean value of 13.648 and a standard deviation of 10.658. Furthermore, financial variables such as ROA, ROE, and NPL are elucidated to provide an overview of the performance and risks inherent to the banking system under examination.

Table 2. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
PENSION	180	7.714	15.9	0	61.214
INSURANCE	180	9.942	12.908	0	50.317
LIFEINS	180	1.482	1.736	0	8.072
FINNOV	180	0	1.815	-2.313	4.557
GRETECH	180	0	2	-3.928	2.836
NONLIFEINS	180	.576	.385	0	1.479
ZSCORE	180	13.648	10.658	0	38.185
ROA	180	1.061	.812	-2.247	3.887
ROE	180	9.785	11.647	-116.199	39.314
NPL	180	2.37	2.588	0	14.4

In this study, a multicollinearity test was conducted to ensure the reliability of the model by identifying any significant correlation between independent variables. This test is important because high multicollinearity can lead to unstable and inaccurate parameter estimates. The multicollinearity test uses the Variance Inflation Factor (VIF) as its main metric, where a VIF value higher than 10 usually signals the presence of serious multicollinearity that can interfere with the regression analysis. The results obtained from the panel analysis show that the VIF values for all variables, including Return on Assets (ROA), Return on Equity (ROE), Bank Z-score (ZSCORE), Financial Innovation (FINNOV), and Non-Performing Loans (NPL) range from 1.04 to 2.46 with an average Mean VIF of 1.62 in each panel assessing the impact of financial innovation on the development of the pension fund and insurance industry (see Table 3). The test results show that there is no alarming indication of multicollinearity in the model, as all VIF values are well below the threshold of 10. This indicates that the independent variables in the model can be considered to have low correlation with each other, thus increasing confidence in the validity of the resulting model estimates.

Table 3. Variance Inflation Factor

Panel 1: The Impact of Financial Innovation on Pension Fund Development (Dependent Variables - PENSION)			**Panel 2:** The Impact of Financial Innovation on the Development of the Insurance Industry (Dependent Variables - INSURANCE)		
Variable	**VIF**	**1/VIF**	**Variable**	**VIF**	**1/VIF**
ROA	2.46	0.405985	ROA	2.46	0.405985
ROE	1.89	0.529558	ROE	1.89	0.529558
ZSCORE	1.59	0.629922	ZSCORE	1.59	0.629922
FINNOV	1.14	0.874336	FINNOV	1.14	0.874336
NPL	1.04	0.96203	NPL	1.04	0.96203
Mean VIF		**1.62**	**Mean VIF**		**1.62**
Panel 3: The Impact of Financial Innovation on the Development of the Insurance Industry (Dependent Variables - LIFEINS)			**Panel 4:** The Impact of Financial Innovation on the Development of the Insurance Industry (Dependent Variables - NONLIFEINS)		
Variable	**VIF**	**1/VIF**	**Variable**	**VIF**	**1/VIF**
ROA	2.46	0.405985	ROA	2.46	0.405985
ROE	1.89	0.529558	ROE	1.89	0.529558
ZSCORE	1.59	0.629922	ZSCORE	1.59	0.629922
FINNOV	1.14	0.874336	FINNOV	1.14	0.874336
NPL	1.04	0.96203	NPL	1.04	0.96203
Mean VIF		**1.62**	**Mean VIF**		**1.62**

In the correlation analysis conducted in this study, the Pearson correlation coefficient was employed to quantify the extent of the linear relationship between the variables involved in the hypothesis testing (see Table 4). The results demonstrate that there is a notable discrepancy in the correlation between the variables, with the p-value associated with each coefficient indicating the statistical significance of the correlation. The variables PENSION and INSURANCE demonstrate a robust correlation, with a coefficient of 0.543, indicating a positive and statistically significant relationship (p-value <0.000). This suggests that both variables exhibit a tendency to increase or decrease in conjunction with one another. The

exceptionally strong correlation between LIFEINS and INSURANCE, with a coefficient of 0.955 (p-value < 0.000), serves to confirm the extremely close relationship between these two insurance sectors within the broader economic context. Furthermore, the FINNOV variable demonstrates a robust positive correlation with INSURANCE and LIFEINS, with coefficients of 0.788 and 0.821, respectively. This suggests that financial innovation exerts a considerable influence on the insurance sector. Conversely, GRETECH also exhibits a substantial positive correlation with the remaining variables, indicating that green technology is inextricably linked to innovation and the insurance sector within the economy. With regard to bank performance variables such as ROA and ROE, the correlations with other variables are relatively lower, indicating that their influence on the pension and insurance sector is less significant than factors such as financial innovation and green technology. Finally, NPLs have varying correlations from low to medium with other variables, suggesting that credit quality in banks has a more limited influence on the development of the pension and insurance sector compared to factors such as financial innovation and technology.

Table 4. Correlation Matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) PENSION	1.000									
(2) INSURANCE	0.543	1.000								
	(0.000)									
(3) LIFEINS	0.544	0.955	1.000							
	(0.000)	(0.000)								
(4) FINNOV	0.526	0.788	0.821	1.000						
	(0.000)	(0.000)	(0.000)							
(5) GRETECH	0.442	0.655	0.649	0.778	1.000					
	(0.000)	(0.000)	(0.000)	(0.000)						
(6) NONLIFEINS	0.657	0.625	0.691	0.695	0.590	1.000				
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)					
(7) ZSCORE	0.304	0.541	0.491	0.286	0.143	0.211	1.000			
	(0.000)	(0.000)	(0.000)	(0.000)	(0.055)	(0.005)				
(8) ROA	0.075	0.055	0.111	0.042	-0.111	0.118	0.518	1.000		
	(0.319)	(0.464)	(0.140)	(0.576)	(0.136)	(0.115)	(0.000)			
(9) ROE	0.089	0.072	0.113	0.066	-0.019	0.143	0.264	0.675	1.000	
	(0.236)	(0.340)	(0.131)	(0.379)	(0.804)	(0.056)	(0.000)	(0.000)		
(10) NPL	0.138	0.076	0.129	0.107	0.306	0.379	-0.072	0.051	0.053	1.000
	(0.065)	(0.312)	(0.085)	(0.153)	(0.000)	(0.000)	(0.334)	(0.493)	(0.481)	

B. Multivariate Statistical Analysis

The Impact of Financial Innovation on Development of Pensions and Insurance

The regression analysis conducted in this study provides an in-depth understanding of the effect of financial innovation on banking stability. From the robust regression results using Ordinary Least Squares (OLS) (see Table 5), we can see that financial innovation (FINNOV) has a significant and positive influence on the development of pension funds and the insurance industry, with very high coefficient values on insurance (4.625, t=17.11) and pension funds (3.954, t=5.83), indicating a strong and statistically significant relationship at the 1% level. Furthermore, control variables such as Bank Z-score (ZSCORE) show that banking system stability, as measured by Z-score, also contributes positively and significantly to the development of the pension fund and insurance industries, with positive coefficients in all models and high significance levels, especially in the insurance industry (0.585, t=7.92). This indicates that higher banking system stability supports the growth of these sectors.

Table 5 presents the results of a robust Ordinary Least Squares (OLS) regression analysis investigating the impact of financial innovation on development of pensions and insurance. The analytical model employed in this study is an OLS regression model: $PENSION_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 \varphi_{i,d} + \epsilon$, $INSURANCE_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 \varphi_{i,d} + \epsilon$, $LIFEINS_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 \varphi_{i,d} + \epsilon$, and $NONLIFEINS_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 \varphi_{i,d} + \epsilon$. The variable $\varphi_{i,d}$ is a control variable consisting of Bank Z-score (ZSCORE), Bank Return on Assets (ROA), Bank Return on Equity (ROE), and Bank Non-Performing Loans (NPL). The table includes regression coefficients and t-statistics $\left(\frac{b}{t_{stat}}\right)$. Robust regressions have been presented to account for heteroscedasticity and autocorrelation. The significance levels are denoted by ***, **, and *, corresponding to levels of 1%, 5%, and 10% respectively.

Table 5. Ordinary Least Squares (OLS) regression analysis of the impact of financial innovation on development of pensions and insurance

	(1) PENSION	(2) INSURANCE	(3) LIFEINS	(4) NONLIFEINS
FINNOV	3.954***	4.625***	0.682***	0.138***
	(5.83)	(17.11)	(15.98)	(10.52)
ZSCORE	0.331***	0.585***	0.0578***	0.000641
	(3.94)	(7.92)	(6.28)	(0.27)
ROA	-2.193	-4.566***	-0.336***	0.0110
	(-1.55)	(-5.25)	(-2.79)	(0.31)
ROE	0.0959	0.102*	0.0110	0.00208
	(1.03)	(1.90)	(1.16)	(1.15)
NPL	0.660	0.254	0.0551**	0.0454***
	(1.37)	(1.65)	(2.09)	(4.32)
_CONS	3.020*	5.197***	0.811***	0.428***
	(1.84)	(5.79)	(6.20)	(11.43)
N	180	180	180	180
R^2-Adj	0.298	0.762	0.753	0.572
F-Statistics	14.25	94.63	77.48	46.19
Prob > F	0.000	0.000	0.000	0.000

Meanwhile, Return on Assets (ROA) shows a mixed relationship across models. In the insurance industry, ROA has a significant negative effect (coefficient -4.566, t=-5.25), suggesting that when banks generate lower profits from their assets, there may be a negative impact on the growth of the insurance industry. This could be due to less effective capital allocation in the banking industry which affects liquidity or investment capacity in the insurance industry. On the other hand, Non-Performing Loans (NPL) shows some significant impact on the premiums of non-life insurance (coefficient 0.0454, t=4.32) and life insurance (0.0551, t=2.09), with significance signalling that poorer credit quality may affect the growth of these industries negatively, possibly due to increased risk and uncertainty in the market.

Robust Ordinary Least Squares regression models were used to examine the specific impact of financial innovation (FINNOV), green technology (GRETECH), and the interaction between the two on the development of the pension fund and insurance industry, and taking into account control variables such as Bank Z-score (ZSCORE), Return on Assets (ROA), Return on Equity (ROE), and Non-Performing Loans (NPL) (see Table 6). From the results obtained, the FINNOV variable shows a significant and positive effect on all sectors studied, with a high positive coefficient indicating that financial innovation improves the performance of the pension and insurance sectors. In particular, in the insurance sector, financial innovation makes the most significant contribution (β=2.698, t=6.42), signalling that the adoption of financial innovation has a major impact on the growth of this industry.

Table 6 presents the results of a robust Ordinary Least Squares (OLS) regression analysis investigating the impact of financial innovation on development of pensions and insurance with mderation green technology. The analytical model employed in this study is an OLS regression model: $PENSION_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 GRETECH_{i,d} + \beta_3 (GRETECH \times FINNOV)_{i,d} + \beta_4 \varphi_{i,d} + \epsilon$, $INSURANCE_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 GRETECH_{i,d} + \beta_3 (GRETECH \times FINNOV)_{i,d} + \beta_4 \varphi_{i,d} + \epsilon$, $LIFEINS_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 GRETECH_{i,d} + \beta_3 (GRETECH \times FINNOV)_{i,d} + \beta_4 \varphi_{i,d} + \epsilon$, and $NONLIFEINS_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 GRETECH_{i,d} + \beta_3 (GRETECH \times FINNOV)_{i,d} + \beta_4 \varphi_{i,d} + \epsilon$. The variable $\varphi_{i,d}$ is a control variable consisting of Bank Z-score (ZSCORE), Bank Return on Assets (ROA), Bank Return on Equity (ROE), and Bank Non-Performing Loans (NPL). The table includes regression coefficients and t-statistics $\left(\frac{b}{t_{stat}}\right)$. Robust regressions have been presented to account for heteroscedasticity and autocorrelation. The significance levels are denoted by ***, **, and *, corresponding to levels of 1%, 5%, and 10% respectively."

Table 6. Ordinary Least Squares (OLS) regression analysis of the impact of financial innovation on development of pensions and insurance with mderation green technology

	(1) PENSION	(2) INSURANCE	(3) LIFEINS	(4) NONLIFEINS
FINNOV	2.237**	2.698***	0.495***	0.144***
	(2.36)	(6.42)	(8.26)	(6.72)
FINNOV×GRETECH	1.443***	1.384***	0.185***	-0.00180
	(4.31)	(10.89)	(8.34)	(-0.21)
GRETECH	1.778**	2.047***	0.188***	-0.00706
	(2.45)	(5.23)	(3.48)	(-0.39)
ZSCORE	0.180**	0.438***	0.0388***	0.000868
	(2.12)	(6.46)	(4.58)	(0.36)
ROA	-0.273	-2.546***	-0.111	0.00609
	(-0.20)	(-3.52)	(-1.02)	(0.18)
ROE	0.0780	0.0820*	0.00910	0.00214
	(0.89)	(1.67)	(1.05)	(1.21)
NPL	0.953**	0.472***	0.1000***	0.0459***
	(2.15)	(2.91)	(3.82)	(4.27)
_CONS	-1.530	0.861	0.225	0.433***
	(-0.81)	(0.92)	(1.62)	(9.39)
N	180	180	180	180
R^2-Adj	0.330	0.818	0.805	0.567
F-Statistics	10.33	122.3	88.21	35.37
Prob > F	0.000	0.000	0.000	0.000

The interaction between FINNOV and GRETECH (FINNOV×GRETECH) also yields highly significant results in all models, suggesting that the synergy between financial innovation and green technology implementation significantly amplifies their respective positive effects in supporting industry stability and growth. In the context of insurance, this interaction is particularly strong (β=1.384, t=10.89), suggesting that the combination of these two factors is critical for insurance industry growth. ZSCORE, which measures the stability of the banking system, shows that higher stability contributes positively to the development of pension funds and insurance, with significant values in all models, especially in the

insurance industry (β=0.438, t=6.46). This confirms that a stable banking system is crucial to support the economic activities of other sectors. ROA and ROE show a more complex relationship, with some results being insignificant or negative, signalling that banks' asset and equity performance has a mixed influence on the various insurance and pension sectors. However, NPLs show a positive influence on the growth of the industry, particularly in the non-life insurance sector (β=0.0459, t=4.27), indicating that good credit risk management is important to support the stability of the sector.

Additional Analysis

Before the pandemic, financial innovation (FINNOV) showed a significant and positive influence on the development of pension funds, insurance, life insurance, and non-life insurance, with coefficients significant at the 1% level for all dependent variables (see Table 7). For example, on the INSURANCE variable, FINNOV shows a coefficient of 4.733 (t = 15.95), signalling that financial innovation significantly boosts the growth of the insurance sector. However, during the COVID-19 pandemic, the effect of financial innovation on PENSION declined and became insignificant (β = 1.863, t = 1.17), while its impact on the insurance sector remained strong and significant, particularly on INSURANCE (β = 5.924, t = 7.29) and LIFEINS (β = 0.997, t = 6.27). This suggests that the insurance sector was better able to adapt to and even benefit from financial innovations during the crisis than the pension sector. In addition, control variables such as Bank Z-score (ZSCORE) still show a positive and significant effect on bank stability, especially before the pandemic, with a coefficient value of 0.607 (t = 8.14) in the insurance sector. However, during the pandemic, the impact of ZSCORE on the insurance sector decreased but was still significant in some sectors, such as LIFEINS (β = 0.0741, t = 2.44).

Table 7 presents the results of a robust Ordinary Least Squares (OLS) regression analysis investigating the impact of financial innovation on development of pensions and insurance before and after the COVID-19 pandemic. The analytical model employed in this study is an OLS regression model: $PENSION_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 \varphi_{i,d} + \epsilon,\ INSURANCE_{i,d} =$

$\beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 \varphi_{i,d} + \epsilon$, $LIFEINS_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 \varphi_{i,d} + \epsilon$, and $NONLIFEINS_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 \varphi_{i,d} + \epsilon$. The variable $\varphi_{i,d}$ is a control variable consisting of Bank Z-score (ZSCORE), Bank Return on Assets (ROA), Bank Return on Equity (ROE), and Bank Non-Performing Loans (NPL). The table includes regression coefficients and t-statistics $\left(\frac{b}{t_{stat}}\right)$. Robust regressions have been presented to account for heteroscedasticity and autocorrelation. The significance levels are denoted by ***, **, and *, corresponding to levels of 1%, 5%, and 10% respectively.

The regression analyses conducted in this study provide an in-depth understanding of the influence of financial innovation on the development of pension and insurance funds, both under the conditions of the global financial crisis and when the crisis did not occur (see Table 8). Other than the period of the global financial crisis, financial innovation (FINNOV) shows a significant and positive influence on all dependent variables, including PENSION, INSURANCE, LIFEINS and NONLIFEINS. For example, on the INSURANCE variable, FINNOV has a coefficient of 4.622 (t = 15.94) which is significant at the 1% level, signalling that financial innovation drives strong growth in the insurance sector. However, during the global financial crisis (2007-2009), although the effect of FINNOV on pension fund development weakened slightly with a coefficient of 3.773 (t = 1.73), its impact on the insurance sector, especially on INSURANCE and LIFEINS, remained significant and even increased. This can be seen in INSURANCE with a coefficient of 6.500 (t = 9.26) and in LIFEINS with a coefficient of 0.889 (t = 9.63). This suggests that financial innovation still plays an important role in supporting the insurance sector despite the stressful economic conditions.

Table 7. Ordinary Least Squares (OLS) regression analysis of the impact of financial innovation on development of pensions and insurance before and after the COVID-19 pandemic

	Before Pandemic COVID-19 (2004-2019)				Pandemic COVID-19 (2020-2021)			
	(1) PENSION	(2) INSURANCE	(3) LIFEINS	(4) NONLIFEINS	(5) PENSION	(6) INSURANCE	(7) LIFEINS	(8) NONLIFEINS
FINNOV	4.792***	4.733***	0.664***	0.143***	1.863	5.924***	0.997***	0.135***
	(6.52)	(15.95)	(17.61)	(9.59)	(1.17)	(7.29)	(6.27)	(4.46)
ZSCORE	0.329***	0.607***	0.0555***	0.000964	0.227	0.420**	0.0741**	-0.00411
	(3.45)	(8.14)	(5.96)	(0.37)	(0.82)	(2.19)	(2.44)	(-0.51)
ROA	-2.329	-4.614***	-0.306***	0.00990	-4.178	-9.730**	-0.990	-0.0174
	(-1.59)	(-5.37)	(-2.73)	(0.27)	(-0.89)	(-2.69)	(-1.63)	(-0.11)
ROE	0.0838	0.0967**	0.00966	0.00211	0.102	0.409	0.0452	-0.000264
	(0.98)	(2.01)	(1.12)	(1.12)	(0.46)	(1.45)	(1.10)	(-0.03)
NPL	0.511	0.192	0.0618**	0.0440***	-0.854	0.131	-0.162	0.0249
	(1.04)	(1.28)	(2.47)	(4.04)	(-0.78)	(0.11)	(-0.89)	(0.68)
_CONS	5.007***	5.778***	0.855***	0.440***	1.503	3.464	0.459	0.496***
	(2.77)	(6.35)	(6.67)	(10.72)	(0.69)	(0.95)	(0.79)	(4.67)
N	160	160	160	160	20	20	20	20
R^2-Adj	0.359	0.779	0.768	0.580	0.000748	0.809	0.779	0.453
F-Statistics	17.26	89.32	99.04	40.22	0.345	14.99	9.074	4.614
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 8 presents the results of a robust Ordinary Least Squares (OLS) regression analysis that investigates the impact of financial innovation on pension and insurance development in years of global financial crisis and years of no global financial crisis. The analytical model employed in this study is an OLS regression model: $PENSION_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 \varphi_{i,d} + \epsilon$, $INSURANCE_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 \varphi_{i,d} + \epsilon$, $LIFEINS_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 \varphi_{i,d} + \epsilon$, and $NONLIFEINS_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 \varphi_{i,d} + \epsilon$. The variable $\varphi_{i,d}$ is a control variable consisting of Bank Z-score (ZSCORE), Bank Return on Assets (ROA), Bank Return on Equity (ROE), and Bank Non-Performing Loans (NPL). The table includes regression coefficients and t-statistics $\left(\frac{b}{t_{stat}}\right)$. Robust regressions have been presented to account for heteroscedasticity and autocorrelation. The significance levels are denoted by ***, **, and *, corresponding to levels of 1%, 5%, and 10% respectively."

The regression analysis conducted in this study provides an in-depth insight into the effect of banking innovation on banking stability, considering the moderating role of green technology before and after the COVID-19 pandemic (see Table 9). Before the pandemic, financial innovation (FINNOV) showed a significant and positive influence on all dependent variables, including PENSION, INSURANCE, LIFEINS, and NONLIFEINS. For example, on the INSURANCE variable, FINNOV has a coefficient of 2.896 (t = 6.34) which is significant at the 1% level, indicating that financial innovation contributed significantly to the growth of the insurance sector. However, during the COVID-19 pandemic, the effect of FINNOV on the PENSION variable became insignificant (β = -1.431, t = -0.69), while its impact on the insurance sector, particularly INSURANCE, remained positive albeit with lower significance (β = 0.793, t = 1.62). This suggests that the pension sector is more vulnerable to economic shocks caused by the pandemic, while the insurance sector is able to maintain its stability even under crisis conditions. The interaction between financial innovation and green technology (FINNOV1×GRETECH) shows significant results before the pandemic, especially on the INSURANCE variable with a coefficient of 1.317 (t = 9.94), suggesting that the combination of financial innovation and green technology adoption amplifies the positive impact on the stability of the insurance sector. During the pandemic, while this

Table 8. Ordinary Least Squares (OLS) regression analysis of the impact of financial innovation on pension and insurance development in years of global financial crisis and years of no global financial crisis

	The global financial crisis did not occur (other than 2007-2009)				A global financial crisis has occurred (2007-2009)			
	(1) PENSION	(2) INSURANCE	(3) LIFEINS	(4) NONLIFEINS	(5) PENSION	(6) INSURANCE	(7) LIFEINS	(8) NONLIFEINS
FINNOV	4.070***	4.622***	0.681***	0.139***	3.773*	6.500***	0.889***	0.160***
	(5.68)	(15.94)	(14.62)	(9.96)	(1.73)	(9.26)	(9.63)	(4.51)
ZSCORE	0.341***	0.589***	0.0592***	-0.000599	0.255	0.433***	0.0358***	0.00441
	(3.58)	(6.93)	(5.51)	(-0.22)	(1.21)	(4.37)	(3.18)	(1.14)
ROA	-1.587	-4.719***	-0.320**	0.0312	-3.553	-4.011***	-0.406***	-0.0471
	(-0.96)	(-4.69)	(-2.26)	(0.73)	(-1.27)	(-3.48)	(-2.86)	(-0.61)
ROE	0.0801	0.0995*	0.00962	0.00163	0.155	0.242*	0.0424**	0.00432
	(0.79)	(1.80)	(1.00)	(0.85)	(0.62)	(1.86)	(2.17)	(0.42)
NPL	0.593	0.385**	0.0597*	0.0440***	0.774	-0.883***	-0.0364	0.0405
	(1.09)	(2.28)	(1.97)	(3.79)	(0.65)	(-2.83)	(-0.66)	(1.43)
_CONS	2.096	4.629***	0.719***	0.418***	6.504	11.51***	1.549***	0.503***
	(1.18)	(4.56)	(4.90)	(10.16)	(1.28)	(6.32)	(5.07)	(5.87)
N	150	150	150	150	30	30	30	30
R^2-*Adj*	0.296	0.750	0.740	0.554	0.218	0.894	0.881	0.652
F-Statistics	11.58	77.88	59.71	36.30	2.913	34.47	35.97	12.05
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

interaction remains significant on some variables such as INSURANCE (β = 4.295, t = 9.08), its impact on other sectors is more varied.

Table 9 presents the results of a robust Ordinary Least Squares (OLS) regression analysis investigating the impact of financial innovation on development of pensions and insurance with moderation green technology before and after the COVID-19 pandemic. The analytical model employed in this study is an OLS regression model: $PENSION_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 GRETECH_{i,d} + \beta_3 (GRETECH \times FINNOV)_{i,d} + \beta_4 \varphi_{i,d} + \epsilon$, $INSURANCE_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 GRETECH_{i,d} + \beta_3 (GRETECH \times FINNOV)_{i,d} + \beta_4 \varphi_{i,d} + \epsilon$, $LIFEINS_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 GRETECH_{i,d} + \beta_3 (GRETECH \times FINNOV)_{i,d} + \beta_4 \varphi_{i,d} + \epsilon$, and $NONLIFEINS_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 GRETECH_{i,d} + \beta_3 (GRETECH \times FINNOV)_{i,d} + \beta_4 \varphi_{i,d} + \epsilon$. The variable $\varphi_{i,d}$ is a control variable consisting of Bank Z-score (ZSCORE), Bank Return on Assets (ROA), Bank Return on Equity (ROE), and Bank Non-Performing Loans (NPL). The table includes regression coefficients and t-statistics $\left(\frac{b}{t_{stat}}\right)$. Robust regressions have been presented to account for heteroscedasticity and autocorrelation. The significance levels are denoted by ***, **, and *, corresponding to levels of 1%, 5%, and 10% respectively.

The OLS regression results presented in Table 10 show the impact of financial innovation on the development of pension and insurance funds with green technology moderation, both in the conditions of the global financial crisis and when the crisis did not occur. Before the global financial crisis, financial innovation (FINNOV) had a significant and positive influence on variables such as PENSION, INSURANCE, LIFEINS, and NONLIFEINS. For example, on the INSURANCE variable, the coefficient of 2.672 (t = 5.52) indicates that financial innovation significantly boosted the growth of the insurance sector. During the global financial crisis period (2007-2009), the impact of FINNOV on the PENSION variable became insignificant (β = -1.451, t = -0.25), but remained significant and positive for the insurance sector, especially on INSURANCE (β = 5.172, t = 3.32). This suggests that financial innovation has an important role in maintaining the stability of the insurance sector despite the unstable economic conditions.

Table 9. Ordinary Least Squares (OLS) regression analysis of the impact of financial innovation on development of pensions and insurance with moderation green technology before and after the COVID-19 pandemic

	Before Pandemic COVID-19 (2004-2019)				Pandemic COVID-19 (2020-2021)			
	(1) PENSION	(2) INSURANCE	(3) LIFEINS	(4) NONLIFEINS	(5) PENSION	(6) INSURANCE	(7) LIFEINS	(8) NONLIFEINS
FINNOV	3.255***	2.896***	0.512***	0.152***	-1.431	0.793	0.0108	0.149**
	(2.96)	(6.34)	(7.85)	(6.31)	(-0.69)	(1.62)	(0.08)	(2.40)
FINNOV×GRETECH	1.614***	1.317***	0.148***	-0.00379	2.414	4.295***	0.753***	0.0175
	(5.18)	(9.94)	(7.81)	(-0.39)	(0.88)	(9.08)	(7.20)	(0.33)
GRETECH	1.708**	2.080***	0.170***	-0.00965	-0.236	-1.444**	-0.130	-0.0548
	(2.04)	(5.35)	(2.92)	(-0.47)	(-0.24)	(-2.36)	(-1.26)	(-1.02)
ZSCORE	0.146	0.447***	0.0385***	0.00147	0.149	0.225***	0.0465**	-0.00756
	(1.45)	(6.35)	(4.20)	(0.57)	(0.62)	(4.17)	(2.88)	(-0.64)
ROA	-0.250	-2.536***	-0.108	0.00189	-2.342	-6.629***	-0.426	-0.0126
	(-0.17)	(-3.37)	(-1.00)	(0.05)	(-0.74)	(-5.24)	(-1.41)	(-0.07)
ROE	0.0699	0.0811	0.00830	0.00217	0.0802	0.389***	0.0394**	0.000620
	(0.84)	(1.59)	(0.96)	(1.18)	(0.51)	(5.06)	(2.20)	(0.06)
NPL	0.856*	0.348**	0.0910***	0.0442***	1.755	4.853***	0.656***	0.0478
	(1.91)	(2.35)	(3.63)	(4.03)	(0.80)	(5.64)	(4.20)	(0.73)
_CONS	-0.0458	1.706*	0.393***	0.451***	-6.182	-9.624**	-1.905**	0.471**
	(-0.02)	(1.79)	(2.79)	(8.95)	(-0.72)	(-2.77)	(-2.91)	(2.85)
N	160	160	160	160	20	20	20	20
R^2-Adj	0.391	0.824	0.799	0.575	-0.0353	0.963	0.944	0.400
F-Statistics	14.06	111.1	110.1	32.79	0.327	101.1	42.76	3.759
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 10 presents the results of a robust Ordinary Least Squares (OLS) regression analysis investigating the impact of financial innovation on development of pensions and insurance with moderation green technology in years of global financial crisis and years of no global financial crisis. The analytical model employed in this study is an OLS regression model: $PENSION_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 GRETECH_{i,d} + \beta_3 (GRETECH \times FINNOV)_{i,d} + \beta_4 \varphi_{i,d} + \epsilon$, $INSURANCE_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 GRETECH_{i,d} + \beta_3 (GRETECH \times FINNOV)_{i,d} + \beta_4 \varphi_{i,d} + \epsilon$, $LIFEINS_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 GRETECH_{i,d} + \beta_3 (GRETECH \times FINNOV)_{i,d} + \beta_4 \varphi_{i,d} + \epsilon$, and $NONLIFEINS_{i,d} = \beta_0 + \beta_1 FINNOV_{i,d} + \beta_2 GRETECH_{i,d} + \beta_3 (GRETECH \times FINNOV)_{i,d} + \beta_4 \varphi_{i,d} + \epsilon$. The variable $\varphi_{i,d}$ is a control variable consisting of Bank Z-score (ZSCORE), Bank Return on Assets (ROA), Bank Return on Equity (ROE), and Bank Non-Performing Loans (NPL). The table includes regression coefficients and t-statistics $\left(\frac{b}{t_{stat}}\right)$. Robust regressions have been presented to account for heteroscedasticity and autocorrelation. The significance levels are denoted by ***, **, and *, corresponding to levels of 1%, 5%, and 10% respectively."

The interaction between FINNOV and green technology (FINNOV1×GRETECH) also shows significant results before the crisis, particularly in INSURANCE with a coefficient of 1.388 (t = 9.56), indicating that synergies between financial innovation and green technology adoption can enhance the stability and growth of the insurance sector. However, during the crisis, these interaction effects are more variable, with some variables such as PENSION showing no significance. Control variables such as ZSCORE also play an important role in this model. Before the crisis, ZSCORE had a positive and significant effect on INSURANCE (β = 0.436, t = 5.49), suggesting that banking stability favoured the growth of the insurance sector. However, during the crisis, the effect of ZSCORE on the PENSION variable becomes insignificant, suggesting that banking stability may have less impact on this sector during the crisis period.

Table 10. Ordinary Least Squares (OLS) regression analysis of the impact of financial innovation on development of pensions and insurance with moderation green technology in years of global financial crisis and years of no global financial crisis

	The global financial crisis did not occur (other than 2007-2009)				A global financial crisis has occurred (2007-2009)			
	(1) pension	(2) insurance	(3) lifeins	(4) nonlifeins	(5) pension	(6) insurance	(7) lifeins	(8) nonlifeins
FINNOV	2.454**	2.672***	0.477***	0.143***	-1.451	5.172***	0.874***	0.246**
	(2.44)	(5.52)	(7.06)	(6.35)	(-0.25)	(3.32)	(3.59)	(2.25)
FINNOV×GRETECH	1.485***	1.388***	0.192***	0.000795	2.312	1.140**	0.112	-0.0415
	(3.96)	(9.56)	(7.62)	(0.09)	(1.23)	(2.10)	(1.34)	(-1.19)
GRETECH	1.527*	1.975***	0.191***	-0.00546	5.024	1.402	0.0381	-0.0835
	(1.94)	(4.20)	(3.07)	(-0.29)	(1.08)	(1.13)	(0.20)	(-0.95)
ZSCORE	0.181*	0.436***	0.0385***	-0.000643	0.106	0.354***	0.0275**	0.00710
	(1.89)	(5.49)	(3.88)	(-0.23)	(0.48)	(3.61)	(2.56)	(1.60)
ROA	0.446	-2.498***	-0.0612	0.0286	-3.846	-3.877**	-0.367*	-0.0435
	(0.26)	(-3.00)	(-0.48)	(0.70)	(-1.06)	(-2.47)	(-1.91)	(-0.70)
ROE	0.0572	0.0717	0.00674	0.00169	0.570	0.370*	0.0478*	-0.00265
	(0.65)	(1.63)	(0.85)	(0.90)	(1.14)	(1.73)	(1.80)	(-0.34)
NPL	0.874*	0.539***	0.0972***	0.0454***	1.652	-0.387	0.0181	0.0244
	(1.69)	(2.88)	(3.18)	(3.74)	(0.88)	(-0.83)	(0.24)	(0.67)
_CONS	-2.330	0.524	0.146	0.416***	-5.754	6.210*	1.096**	0.719***
	(-1.13)	(0.50)	(0.94)	(8.50)	(-0.50)	(1.91)	(2.20)	(3.24)
N	150	150	150	150	30	30	30	30
R^2-Adj	0.328	0.808	0.797	0.548	0.228	0.908	0.898	0.652
F-Statistics	8.465	107.5	70.81	26.47	1.861	31.42	40.35	32.41
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Discussion

The results of this study confirm that financial innovation has a significant and positive influence on the development of pension funds and the insurance industry, which is in line with the findings of previous literature. As highlighted by Bara & Mudzingiri (2016), financial innovation plays an important role in driving economic growth through the creation of new economic initiatives. This study supports this view by showing that innovation in the banking sector, as measured through its impact on pension funds and insurance, reflects improved operational efficiency and better risk management. Furthermore, this study is consistent with the findings of Liu (2022), who showed that financial innovation can improve the financial performance of banks, which in this context is seen from the contribution of banking stability to the growth of the pension and insurance fund sector. This finding is also in line with the research of Omollo et al. (2022) who identified financial services diversification as a key factor in supporting financial progress and expanding market access. In this context, financial innovation not only supports the stability of the banking system but also encourages the development of related sectors such as pension funds and insurance, as suggested by Kolodiziev et al. (2021) that pension fund asset management is a key driver of financial performance and fulfils the need for financial innovation. The research also confirms the importance of effective risk management and governance, as emphasised by Wiß (2014), to ensure the long-term sustainability of these financial entities amidst increasingly complex challenges.

The results of this study show that green technology strengthens the relationship of financial innovation to the development of the insurance and pension fund sector. As stated by Alda (2019), the increasing influence of green technology has encouraged pension funds to adopt ecologically sustainable activities, reflecting the role of innovation in creating new environmentally friendly investment strategies. This research strengthens the argument by showing that financial innovation contributes greatly to the growth of the insurance industry, especially in the context of green insurance, as highlighted by Pu (2024) that green insurance acts as a catalyst for green innovation in the insurance business. In addition, this

research is also in line with the findings of Le (2024) who stated that green financial activities enhance ecological resilience through information transparency and green credit evaluation systems, which can be applied in pension fund management. Furthermore, this study supports the view of Croce et al. (2011) that pension funds play an important role in supporting sustainable green energy projects, such as hydroelectricity, by providing significant financial support. In this context, the results show that the adoption of financial innovations not only improves the performance of the insurance sector but also contributes to the transformation of pension funds' investment strategies towards sustainability.

V. Conclusions

This study aims to examine the impact of financial innovation on the development of pension and insurance systems in ASEAN countries. The results show that financial innovation has a positive and significant influence on both sectors, especially in terms of improving operational efficiency and risk management. The findings indicate that the adoption of new financial technologies and innovative strategies can foster sustainable growth in the pension and insurance industries. Furthermore, financial innovations have been shown to contribute greatly to strengthening financial stability in the sector, which in turn can improve the welfare of people who depend on pension and insurance services. The research also revealed that the application of green technology in pension and insurance management plays an important role in supporting environmental sustainability, while also delivering positive economic impacts. Thus, financial innovation not only advances the financial sector, but also plays a key role in the transformation of pension and insurance systems towards greater sustainability in ASEAN countries. This conclusion reinforces the importance of policies that support financial innovation as one of the key strategies to strengthen financial systems in the region.

This research makes an important contribution theoretically by expanding the understanding of the impact of financial innovation on the stability of the pension and insurance sectors in ASEAN countries. Practically, the findings emphasise the need for financial institutions to

continue adopting and developing financial innovations to improve operational efficiency and competitiveness in an increasingly dynamic market. However, this study has some limitations, including limited sample coverage to ASEAN countries and the use of certain variables that may not fully reflect the complexity of global financial markets. Therefore, future research agenda could focus on expanding the geographical coverage and using more comprehensive analytical methods to examine the deeper relationship between financial innovation and financial sector stability across different economic contexts. Future research could also consider additional variables such as the impact of regulation and more specific technological changes to provide richer insights into risk management strategies and innovation in the financial industry.

VI. Policy Recommendations

Based on the research results, it is recommended that the government and financial authorities strengthen policies that encourage financial innovation in the pension fund and insurance sectors. Firstly, it is important to increase investment in green technology, as results show that the combination of financial innovation and green technology can strengthen financial sector stability and growth, especially during economic crises. The government should provide fiscal incentives such as tax breaks or subsidies for companies investing in green technologies that support sustainable finance practices.

In addition, banking authorities should ensure that the banking system remains stable by continuously monitoring stability indicators such as Bank Z-score and Non-Performing Loans (NPL). Stricter supervision of banks' credit risk and asset management is essential, especially during times of financial crisis, to minimise negative impacts on the insurance and pension sectors.Furthermore, to enhance the resilience of the financial sector to global shocks, policies that encourage diversification of innovative insurance and pension products are needed. Finally, financial authorities should strengthen the regulatory framework that promotes transparency and accountability in the management of green investments, to ensure that the financial sector not only grows

quantitatively, but also contributes to sustainable development. By doing so, the financial sector can play a greater role in supporting inclusive and sustainable economic growth in the future.

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