# CHAPTER IV

# RESULTS AND DISCUSSION

## 4.1 Results

The results and discussion chapter of the study delves into the essence of the research by presenting and discussing the principal findings derived from various conducted studies. The chapter initiates an examination of the distinct characteristics of each variable through descriptive statistics, such as mean, median, standard deviation, and skewness, to understand the foundational structure of the data. The subsequent section elaborates on the rationale behind selecting components and their functions in capturing fundamental relationships in the data using Principal Component Analysis indices, which aids in reducing dimensionality and enhancing interpretability for further analysis.

Furthermore, the chapter explores the connections among variables through Pearson correlation analysis, shedding light on the magnitude and correlation of relationships between variables to identify potential explanatory factors influencing the target outcome. Scrutiny of core assumptions of statistical models, including assessments for normality, multicollinearity, and heteroscedasticity, is conducted critically to ensure data reliability for analysis.

The chapter proceeds to evaluate regression analyses aligned with study objectives and hypotheses, assessing model fit, estimated coefficients, and significance levels to understand relationships between dependent and independent variables influencing the target result. Additionally, the chapter extends beyond initial regression results by conducting sensitivity studies to assess the effects of potential data management modifications and model assumptions, ensuring the dependability and applicability of findings.

Robustness tests are executed to evaluate the consistency of outcomes under different assumptions or estimation techniques, reinforcing confidence in the study's results. This comprehensive approach strengthens the validity of the findings obtained from the research inquiry, providing a robust foundation for further discussion and implications of the study's outcomes.

## 4.2 Descriptive Statistics

Table 4.1 presents descriptive statistics about key variables that are pertinent to the examination of financial development, economic growth, and resilience in SSA countries. The findings offer a concise overview of the research variables, including their respective average values and standard deviations (range). While a thorough analysis of these data may yield valuable insights, additional statistical techniques are necessary to explore potential relationships among variables.

Table 4.1 Table Descriptive statistics

| Variable | Mean | Std. Dev. | Min | Max | Obs |
|---|---|---|---|---|---|
| FinL | 1.818 | 0.211 | 1.018 | 2.390 | 815 |
| FinII | 17.398 | 8.227 | 1.930 | 71.890 | 846 |
| lnFinAI | 3.235 | 0.571 | -0.430 | 4.160 | 846 |
| lnCChI | 8.566 | 1.494 | 3.920 | 11.590 | 846 |
| lnFinSI | 3.311 | 0.259 | 2.460 | 3.860 | 846 |
| GDPGR | 1.275 | 4.538 | -36.778 | 19.939 | 840 |
| REQua | -0.729 | 0.651 | -2.548 | 1.197 | 844 |
| FDevI | 0.363 | 0.232 | 0.000 | 0.974 | 846 |
| lnTop | 4.163 | 0.477 | 0.993 | 5.463 | 841 |
| ATech | 16.616 | 18.178 | 0.215 | 94.006 | 844 |
| PoS | -0.583 | 0.911 | -3.313 | 1.201 | 844 |
| EduA | 40.568 | 21.254 | 2.392 | 95.100 | 841 |
| lnGNIPc | 7.301 | 0.959 | 5.389 | 9.768 | 844 |
| Gini Index | 40.378 | 16.076 | 6.720 | 71.239 | 841 |

*Note(s). FinL: Financial Literacy, FinII: Financial Inclusion Index, lnFinAI: Natural logarithm of FinTech Adoption Index, lnCChI: Natural logarithm of Climate change Index, lnFinSI: Natural logarithm of Financial Stability Index, GDPGR: Gross Domestic Product Growth Rate: REQua: Regulatory Quality, FDevI: Financial Development Index, lnTop: Natural logarithm of Trade openness, ATech: Access to Technology, PoS: Political Stability, EduA: Education Attainment, lnGNIPc: Natural logarithm of Gross National income Per Capita (income level). Gini Index: Income Distribution*.

Source: Author's Estimate (2024)

### 4.2.1 Financial literacy

SSA presents a captivating yet complex picture when it comes to financial literacy. While the average score on financial literacy assessments sits around 1.818, the standard deviation of 0.211 paints a more nuanced picture. This significant variation highlights the vast differences in financial knowledge across the region (World Bank, 2022). It underscores a critical need for financial literacy initiatives that resonate with the unique realities of individual SSA countries. In Ghana, for

example. Despite a commendable overall financial literacy rate, with roughly 50% of the adult population answering 3 out of 7 financial literacy assessment questions correctly, certain regions still show significant knowledge gaps. Research by Karakara et al. (2021) emphasizes that tailoring programs to these specific regional needs, not just national averages, is key to effectiveness. This targeted approach can address inconsistencies and elevate the financial acumen of the entire population.

Nigeria presents a different challenge. While the national average hovers around 38% with a similar benchmark (3 out of 7 correct), a significant gap exists in utilizing financial services, particularly in rural areas. Here, only about 25% of adults have a formal bank account (World Bank, 2022). This disconnect highlights the need for financial literacy programs that address specific barriers to financial inclusion. Initiatives promoting mobile financial services education could leverage Nigeria's growing digital infrastructure, where mobile money adoption already boasts a rate of over 80%. By bridging the gap between knowledge and access, these programs can empower Nigerians to participate more fully in the formal financial sector.

South Africa stands out with its relatively high financial literacy rate of around 60%, with a substantial portion of the population answering at least 3 out of 7 questions correctly. However, this also presents an opportunity for further advancement. Integrating more complex topics like investment and risk management can not only sustain current levels but also enhance financial decision-making across a broader population, fostering a more resilient economic environment. Moreover, Kenya serves as a powerful example of how practical financial literacy, particularly in digital finance, can lead to significant gains in financial inclusion. With a mobile money adoption rate exceeding 85%, Kenya boasts a financial literacy rate of around 40%, with a significant portion of the population answering at least 3 out of 7 questions correctly on financial literacy assessments (World Bank Group, 2022). Here, financial literacy programs should continue to emphasize digital financial services, which are becoming increasingly central to personal finance management in the region.

In contrast, countries like Sudan, with a financial literacy rate as low as 15% (with a much smaller proportion answering 3 out of 7 questions correctly), require

foundational financial education programs (World Bank Group, 2022). These initiatives should focus on basic financial concepts like saving, budgeting, and the benefits of engaging with the formal financial sector. Building this foundational knowledge is crucial for fostering the confidence needed to utilize financial institutions and services. Uganda, with its moderate financial literacy levels of around 34% (demonstrated by a moderate proportion answering 3 out of 7 questions correctly), presents an opportunity for growth through focused and continuous financial education efforts. Programs could benefit from incorporating elements successful in similar economies, such as mobile banking education and financial planning for small businesses, which are the backbone of Uganda's economy.

### 4.2.2 Financial inclusion

The Financial Inclusion Index paints a complex picture of financial access in SSA. While the average score of 17.398 suggests a moderate level of participation (Bull & Klapper, 2023). The findings show a significant segment of the population in SSA region still lacks access to essential financial services like credit, insurance, and savings accounts. This finding aligns with research by Ofoeda et al. (2024) who highlight the persistent inequalities in accessing formal financial services across the region, with a mean score that might not reflect the experiences of a significant portion of the population. Limited financial inclusion presents a multitude of challenges. Individuals are hindered from building a secure financial future through saving and investing. Additionally, they are left vulnerable when faced with financial emergencies, unable to access mechanisms to weather financial storms (Bull & Klapper, 2023). Businesses too, grapple with restricted access to financing, which stifles their potential for growth and job creation. To address these challenges and bridge the financial divide, policy initiatives that promote financial inclusion are crucial.

Mobile banking has emerged as a powerful solution, with studies like that of Gao et al. (2024) highlighting its success in extending financial services to underserved and rural communities. Kenya serves as a prime example. Boasting a mobile money adoption rate exceeding 85%, the country is a leader in leveraging mobile technology for financial inclusion (Hannes & Truyen, 2023). Initiatives like M-Pesa have revolutionized access to financial services, particularly for the

unbanked population. This success story offers a blueprint for other SSA nations aiming to expand financial inclusion. Nigeria presents another promising case study. Here, with a mobile money adoption rate exceeding 80%, leveraging the existing mobile infrastructure is key to expanding financial inclusion (Demirgüç-Kunt et al., 2022). Particularly in rural areas, where only about 25% of adults have a formal bank account, mobile banking offers a pathway to financial inclusion. By promoting mobile financial literacy and building upon the established mobile ecosystem, Nigeria can empower a significant portion of its population.

Microfinance plays another critical role by providing modest financing and financial services to individuals and small businesses that may not qualify for traditional banking products. This is particularly important in countries like Uganda (financial inclusion index score: 28) and Tanzania (score: 34) (Bull & Klapper, 2023). Both nations present significant opportunities for growth in financial inclusion. Microfinance initiatives that target small businesses, the backbone of these economies, can be a powerful tool. Research by Gutiérrez-Nieto and Serrano-Cinca (2023) highlights the positive impact of microfinance in fostering financial inclusion.

While the financial inclusion index provides a general overview, it's crucial to delve deeper into the underlying statistics of specific countries to understand the true extent of the challenge. Governments across SSA play an indispensable role in advancing financial inclusion. Rwanda, for instance, has prioritized investment in digital infrastructure and implemented policies that support mobile banking capabilities, fostering a more inclusive financial landscape (World Bank, 2022). Similarly, Ghana is actively promoting collaborations between traditional financial institutions and innovative finTech firms. This collaboration can foster financial inclusion by leveraging the strengths of both sectors and promoting financial innovation.

### 4.2.3 FinTech adoption

SSA is witnessing a dynamic transformation in its financial landscape, fueled by the burgeoning fintech ecosystem. While the FinTech Adoption Index, with an average value of 3.235, suggests a nascent stage, the potential for growth is nothing short of remarkable. This aligns with research by Tao et al. (2022) who emphasize

fintech's potential to bridge the financial inclusion gap and propel regional economic development. Understanding how specific SSA countries are leveraging fintech and the impact it's having is crucial. Kenya stands as a prime example. Boasting a mobile money adoption rate exceeding 85%, Kenya has pioneered the use of mobile platforms like M-Pesa to revolutionize financial access, particularly for the unbanked population (Mbiti & Weil, 2018). This success story has inspired other SSA nations like Nigeria, where a mobile money adoption rate exceeding 80% presents a similar opportunity. By leveraging the existing mobile infrastructure and promoting mobile financial literacy, Nigeria can empower a significant portion of its population who currently lack access to formal bank accounts (C. Zheng & Z. Sun, 2023).

FinTech goes beyond just mobile money. In Rwanda, for instance, where the FinTech Adoption Index score is higher than the regional average, a focus on digital lending is proving transformative. Recognizing the critical role of small and medium-sized enterprises (SMEs) in the Rwandan economy, fintech solutions are being designed to provide these businesses with easier access to credit, fostering growth and job creation (Song & Hao, 2024) Financial inclusion is not just about access to credit, but also about efficient money management. Ghana, with a FinTech Adoption Index score above the regional average, is at the forefront of innovation in this area. Fintech startups in Ghana are developing digital wallets and budgeting apps tailored to the specific needs of the local population. This not only promotes financial literacy but also empowers individuals to manage their finances more effectively (World Bank, 2022).

The impact of fintech extends beyond financial inclusion. By streamlining financial processes and reducing transaction costs, fintech can significantly enhance the efficiency of the financial sector. A study by Senyo et al. (2022) underlines how FinTech adoption reduces reliance on traditional banking infrastructure, leading to cost savings for both financial institutions and their clients. This fosters a more competitive financial landscape, ultimately benefiting consumers. Fintech can also be a catalyst for innovation. By customizing financial products and services to address the unique challenges of SSA economies, fintech can unlock new opportunities. For example, the case of Ethiopia, where a recent surge in fintech

adoption is underway. Here, innovative insurance products targeted at smallholder farmers are being developed using big data and analytics. These products can protect farmers against climate risks and promote financial resilience in rural communities (World Bank, 2022).

The FinTech revolution in SSA is still in its early stages, as evidenced by the FinTech Adoption Index. However, the potential for growth is undeniable. By harnessing the power of fintech to expand financial inclusion, improve efficiency, and foster innovation, Sub-Saharan Africa can bridge the financial gap and unlock its full economic potential. As Hasan et al. (2024) highlight, a thriving fintech ecosystem can empower businesses and individuals, ultimately propelling economic development across the region. The future of finance in SSA is undeniably digital, and FinTech holds the key to unlocking a more inclusive and prosperous future for all.

**4.2.4 Climate change**

The high average climate change vulnerability index score of 8.566 paints a grim picture, highlighting the region's extreme susceptibility to the dangers of climate change (Alare et al., 2022). This vulnerability stems from a potent combination of factors: dependence on natural resources for livelihoods and limited economic development (He et al., 2022). Building resilience is no longer a choice, but a necessity for the region's long-term financial stability, economic growth, and overall well-being. Climate change presents a complex web of threats with far-reaching consequences. Studies by Baptista et al. (2022a) warn of potential risks to financial stability arising from damaged infrastructure, disrupted economic activity, and a devaluation of assets. These cascading effects can cripple economies and plunge populations into deeper poverty.

However, amidst the challenges lie opportunities. Financial literacy holds immense power in this fight. Empowering individuals and businesses with financial knowledge allow them to invest in climate-resilient technologies and mitigate climate-related risks. Understanding the potential financial impact of climate change can incentivize investments in energy-efficient equipment or climate-resistant crops. Take Ethiopia, for instance, where droughts are a recurring threat. By educating farmers about the financial benefits of drought-resistant crops,

financial institutions can empower them to invest in these technologies, safeguarding their livelihoods and ensuring food security (World Bank, 2022).

Financial inclusion plays a critical role in supporting vulnerable populations in weathering the storms of climate change. Studies by Bouraima et al. (2024) showcase the impact of microfinance organizations in Bangladesh, where loans enabled farmers to adopt climate-resilient agricultural practices. Similarly, microfinance institutions in Senegal are providing loans to smallholder farmers for investments in drought-resistant seeds and irrigation systems, empowering them to adapt to changing weather patterns. Beyond adaptation, climate change presents an opportunity to drive economic growth through the promotion of sustainable infrastructure and renewable energy. Bhattacharya et al. (2023) point to examples like China and India, where investments in these areas have led to increased employment and economic development. Kenya, a country grappling with climate change-induced energy insecurity, is at the forefront of this movement. By investing heavily in geothermal and solar energy production, Kenya is not only reducing its dependence on fossil fuels but also creating new jobs in the clean energy sector (Udeagha & Breitenbach, 2023).

Investing in climate-smart agriculture is another crucial step towards building resilience. Drought-resistant crops, water-efficient irrigation techniques, and improved soil management practices can significantly enhance a farmer's ability to withstand climate shocks. In Rwanda, for instance, government initiatives are promoting the use of cover crops and rainwater harvesting techniques, helping farmers adapt to changing weather patterns and reduce their vulnerability to droughts. Green bonds offer a promising avenue for financing climate-resilient projects. These bonds, as reported by Raihan et al. (2022), have witnessed a significant rise in issuance, reflecting a growing global commitment to sustainable development. However, a significant financing gap remains, particularly for developing countries like those in SSA. Innovative financial mechanisms and increased international cooperation are crucial to bridge this gap and ensure that SSA has the resources it needs to adapt to climate change and build a more resilient future. The future of SSA is intricately linked to its ability to navigate the challenges of climate change.

### 4.2.5 Financial stability

Financial stability is the cornerstone of a healthy economy, and SSA presents a complex picture in this regard. Statistical analysis of the financial stability index unlocks valuable insights into the region's economic health and resilience. While the average score of 3.311 suggests a moderate level of financial stability across the region (source needed), the standard deviation of 0.259 paints a more nuanced picture, revealing significant variation among countries. This range, from 2.460 to 3.860, highlights the need for targeted approaches to strengthen financial systems in nations with lower scores. Understanding financial stability goes beyond averages. Research by S. Claessens et al. (2018) and Jungo et al. (2022) underscores the critical role a robust financial system plays in fostering economic development. For instance, a country like Mauritius, with a financial stability index score above the regional average, boasts a well-developed financial sector that facilitates investment and business growth. In contrast, a nation like South Sudan, with a score on the lower end of the spectrum, faces challenges in attracting investment due to a less stable financial system, hindering economic development.

Variations in financial stability scores highlight the need for tailored policy interventions. As the Ozili (2024) suggests, countries with lower scores require more targeted efforts to strengthen their financial systems. This might involve stricter regulations for banks, improved risk management practices, or fostering a more competitive financial landscape. Rwanda, for example, has undertaken significant reforms to enhance its financial stability score, focusing on improving regulatory frameworks and promoting financial inclusion. Financial stability isn't just about economic growth; it's also about reducing systemic risks and fostering inclusive development. Demirgüç-Kunt et al. (2022) emphasize the importance of analyzing the financial stability index for this very reason. A stable financial system safeguards the economy from financial crises that can disproportionately impact vulnerable populations. Consider Ghana, a country working towards financial stability.

Examining the distribution of financial stability levels allows policymakers to design effective strategies. Research by Kaur (2023a) highlights the importance of tailoring these strategies to address specific vulnerabilities within a country. For

instance, a nation with a high level of financial stability but low access to financial services for rural populations might require policies focused on financial inclusion initiatives, like mobile banking or microfinance programs. The financial stability landscape in Sub-Saharan Africa is far from homogenous. This knowledge empowers them to design targeted interventions that strengthen financial systems, reduce risks, and pave the way for sustainable and inclusive economic growth across SSA. Thus, a financially stable Sub-Saharan Africa is not just a statistic, but a springboard for a more prosperous and resilient future for all (Demertzis et al., 2019; Maimbo et al., 2011).

### 4.2.6 Economic growth

Economic growth, as measured by the Gross Domestic Product Development Rate, is the lifeblood of a nation's progress stood at 1.275. However, in SSA, the economic growth is far from uniform. The high standard deviation of 4.538 in the GDPGR paints a picture of vast disparities between countries. This variability underscores the complex interplay of factors influencing economic performance in the region. Fluctuating economic structures play a significant role. Countries like Ethiopia, with a GDP growth rate exceeding 8% (Pandey et al., 2023), are experiencing a boom driven by strong public investment in infrastructure and a growing manufacturing sector. In contrast, nations reliant on commodities like oil, such as Angola (whose GDP growth is hovering around 1% due to fluctuating oil prices) face challenges in diversifying their economies.

Policy environments also significantly impact growth. Rwanda, with a focus on creating a business-friendly environment and attracting foreign investment, has seen consistent economic growth averaging over 7% in recent years (World Bank, 2022). On the other hand, political instability and corruption in countries like the Democratic Republic of Congo (DRC) stifle economic activity, leading to a negative GDP growth rate. External disruptions can further complicate the growth path. The recent global economic slowdown, coupled with the ongoing war in Ukraine, has impacted SSA through rising food and energy prices. Countries like South Africa, a major regional economy, are experiencing slower growth due to these external factors (Tsuchiya, 2023).

The high standard deviation in GDPGR highlights the need for customized policy approaches. A one-size-fits-all solution won't suffice. Banna and Alam (2021a) emphasize the importance of tailoring policies to address the unique circumstances of each country. Ethiopia's focus on infrastructure and manufacturing may not be the answer for a landlocked country like Malawi, where agricultural development and promoting regional trade might be more crucial. Furthermore, the erratic nature of economic performance necessitates proactive measures. As the World Bank (2021) suggests, policymakers must be prepared to navigate unforeseen challenges. Building resilience through economic diversification and promoting financial inclusion can help buffer against external shocks.

Investing in strategic areas like infrastructure, human capital, and technological innovation is essential for sustained growth. Tsuchiya (2023) rightly emphasizes the importance of these investments. Upgrading transportation networks in countries like Kenya can facilitate trade and unlock economic potential. Similarly, investments in education and skills training in Ghana can empower its workforce and drive innovation in key sectors. The economic landscape of Sub-Saharan Africa is a mosaic of growth rates. While some countries are experiencing rapid economic expansion, others face significant challenges. Recognizing the reasons behind this disparity and implementing targeted policies are crucial for ensuring inclusive and sustainable economic growth across the region. By harnessing the potential of its people and resources, Sub-Saharan Africa can rewrite the narrative and chart a course towards a more prosperous future.

### 4.2.7 Regulatory quality

The Regulatory Quality indicator acts as a barometer for the efficiency and effectiveness of a nation's regulatory framework. In SSA, the negative mean value of -0.729 for REQua in a dataset of 844 observations paints a concerning picture. This suggests that, on average, regulatory burdens are potentially hindering economic activity across the region. Research by Gichuru and Namada (2022) underlines the critical role regulatory quality plays in influencing investment decisions, business environments, and overall economic performance. A nation like Mauritius, boasting a positive regulatory quality score, benefits from a streamlined regulatory framework that attracts foreign investment and fosters business growth.

Conversely, countries with a negative regulatory quality score, like the Democratic Republic of Congo (DRC), often grapple with excessive regulations that stifle entrepreneurial activity and hinder economic development.

The negative regulatory quality in SSA indicates potential inefficiencies within regulatory frameworks. Bekana (2023) highlights the detrimental impact of burdensome regulations, such as complex compliance requirements and excessive bureaucracy. These hurdles can discourage entrepreneurship, deter investment, and cripple business development plans. For instance, a country like Nigeria, with a significant informal economy, might benefit from streamlining business registration processes to encourage formalization and economic growth. The path forward lies in striking a balance between financial stability and economic growth. Policymakers and regulatory bodies must prioritize improving regulatory frameworks. As Falchetta et al. (2021) suggest, this involves streamlining processes, eliminating outdated regulations, and promoting transparency and predictability. Rwanda, for example, has undertaken significant reforms to improve its regulatory environment, focusing on simplifying business registration and fostering public-private partnerships (Tsuchiya, 2023).

Enhancing the efficiency and effectiveness of regulatory systems is vital. Abrahams et al. (2024) propose a multi-pronged approach. Implementing risk-based regulations that target high-risk activities while streamlining processes for low-risk ones can be a game-changer. Utilizing data analytics and technology can also improve regulatory compliance monitoring, freeing up resources for other areas. Furthermore, fostering collaboration and communication between regulatory bodies and industry stakeholders is crucial. Open dialogue allows for a deeper understanding of industry needs and helps tailor regulations that are both effective and growth-oriented.

Regulatory reform must be grounded in principles of good governance. Levi-Faur (2023) emphasizes the importance of transparency, accountability, and stakeholder engagement. This ensures that reforms are proportionate, evidence-based, and aligned with broader economic objectives. For instance, a country like South Africa, with a well-developed legal framework, can leverage its strengths to promote transparency in regulatory processes, fostering trust and encouraging

investment. SSA's economic potential is undeniable. However, a negative regulatory quality score highlights the need to address regulatory burdens. Prioritizing reform, striking a balance between stability and growth, and embracing good governance principles, SSA nations can create a more conducive environment for business activity, attract investment, and unlock their full economic potential. A future where regulations empower, rather than hinder, is within reach, paving the way for a more prosperous and vibrant SSA.

### 4.2.8 Financial development

The financial development index serves as a compass, guiding our understanding of a region's financial landscape. In SSA, the financial development index for 846 observations sits at a moderate 0.363. While this indicates progress, it also underscores the need for further development. Financial development is a multifaceted concept encompassing the robustness, efficiency, depth, and breadth of financial institutions and markets (Ofori-Acquah et al., 2023). The moderate financial development index in SSA highlights the importance of continued efforts to strengthen financial infrastructure and institutions. Kenya, for example, boasts a relatively well-developed mobile money sector, but challenges persist in areas like access to credit, particularly in rural areas (World Bank, 2022).

There are several key areas for improvement. Enhancing the availability of financial services is crucial. This could involve expanding access to bank accounts, offering microloans to small businesses, and developing insurance products tailored to the needs of the population. Ghana, for instance, has seen positive developments in mobile banking, but challenges remain in providing financial services to the unbanked population (World Bank, 2022). Financial inclusion goes hand-in-hand with product diversification. As Giordino and Revello (2023) suggest, introducing new financial products like micro-insurance or investment options targeted at specific demographics can be a growth driver. Rwanda, with its focus on financial inclusion through mobile money and digital payments, can leverage this foundation to introduce new investment products for its growing middle class.

Financial infrastructure also plays a critical role. A robust financial infrastructure, encompassing efficient payment systems, reliable credit reporting mechanisms, and a sound regulatory framework, facilitates the flow of capital,

reduces transaction costs, and fosters trust in the financial system (Abeka et al., 2021). South Africa, with its relatively developed financial infrastructure, can serve as a model for other SSA countries seeking to improve efficiency and transparency. Regulations are the cornerstones of a healthy financial system. Effective regulations that promote transparency, accountability, and competition are essential for fostering financial development (Bekana, 2023). A well-defined regulatory framework safeguards consumer interests, protects market integrity, and attracts investment. Nigeria, for example, has undertaken reforms to strengthen its regulatory framework, focusing on improving banking supervision and consumer protection.

Financial literacy is another crucial element. Koketso Molefhi (2019) emphasizes the importance of educating the public about financial products and services. Equipping individuals with the knowledge to manage their finances effectively fosters economic inclusion and empowers them to make informed financial decisions. Ethiopia, with its growing youth population, can prioritize financial literacy programs to ensure this demographic can participate fully in the financial system. SSA's financial sector is on an upward trajectory. However, the moderate financial development score serves as a reminder that there's still work to be done. By expanding financial services, diversifying products, strengthening infrastructure, and prioritizing financial literacy, SSA can build a more robust and inclusive financial system, paving the way for a more prosperous future. As the financial sector deepens and broadens, it can act as a catalyst for unlocking the full economic potential of the region.

### 4.2.9 Trade openness

SSA exhibits a moderate level of trade openness, with a Trade Openness statistic of 4.163. This score, based on an analysis of 841 observations, suggests that the region is moderately integrated into the global trading system. While not fully open, this position offers significant potential for economic growth through deeper integration and information exchange. Trade openness is a double-edged sword. Increased participation in international commerce brings several benefits. Specialization and economies of scale, as highlighted by D. Makina (2019), allow countries to focus on producing goods and services where they have a comparative

advantage. This can lead to higher efficiency and lower production costs. For instance, a country like Ethiopia, with a well-developed coffee industry, can benefit from specializing in coffee production and exporting it to the global market.

Trade openness also unlocks access to new markets. Laeven et al. (2015) emphasizes how participation in international trade exposes countries to a wider range of goods and services. This can foster innovation and technology transfer, as nations learn from global best practices and compete with international players. South Africa, the most economically developed nation in SSA, benefits from its openness, attracting foreign investment and technology in various sectors like mining and telecommunications. Furthermore, trade openness can act as a catalyst for economic growth. Abrahams et al. (2024) highlight the role of trade in promoting export-oriented development and attracting foreign capital. Countries like Ghana, which have actively pursued trade agreements and lowered trade barriers, have seen a rise in exports of manufactured goods and increased foreign direct investment.

However, a moderate level of trade openness also suggests a cautious approach. Policymakers strive for a balance between promoting openness and protecting domestic industries. Teichmann and Wittmann (2022) advocate for balanced trade policies that encourage international trade while safeguarding local businesses from unfair competition. Countries like Tanzania, for example, may use tariffs or import quotas on certain goods to protect nascent industries while still allowing participation in global trade.

Trade openness also enhances economic resilience. The World Bank Group (2022) points out that diversification of income sources through trade reduces dependence on local markets. This can help countries weather economic downturns and capitalize on new opportunities in the global arena. A nation like Kenya, with a diversified export base that includes tourism, agricultural products, and manufactured goods, is better equipped to handle fluctuations in global commodity prices compared to a country reliant on a single export.

### 4.2.10 Access to technology

The state of technology access in SSA is one of stark contrasts. A high standard deviation of 18.178 in access to technology statistics paints a picture of vast

disparities between countries. While some nations are embracing the digital revolution, others face significant hurdles. Understanding this digital divide is crucial for unlocking the region's full potential. The root of the problem lies in uneven digital adoption and infrastructure. D. Salampasis and A. L. Mention (2018) highlight this gap, emphasizing how discrepancies in these areas hinder technological progress. A country like Mauritius, with a relatively high internet penetration rate exceeding 80% (World Bank, 2023b), stands in stark contrast to nations like Niger, where internet penetration hovers around 20% (World Bank, 2023). This limited access stifles innovation, hinders financial inclusion, and restricts participation in the digital economy.

The consequences of the digital divide are far-reaching. Financial inclusion initiatives, crucial for poverty reduction and economic growth, face significant challenges in nations with limited tech access (Huang et al., 2022). For instance, a nation like the Democratic Republic of Congo (DRC), with a large unbanked population, could leverage mobile banking technologies to expand financial inclusion. However, limited internet access and low digital literacy rates can impede such efforts. Bridging the digital divide requires a multi-pronged approach. Targeted policies and resource allocation are crucial. Upgrading broadband infrastructure, as advocated by D. Salampasis and A. L. Mention (2018), is essential. Countries like Kenya, with its ambitious national broadband plan, are taking steps to improve internet connectivity across the nation (World Bank, 2023).

Digital literacy is another key battleground. Equipping individuals with the skills to navigate the digital world is essential. Initiatives like Rwanda's coding academies, which provide training in software development, empower young people to participate in the digital economy (World Bank, 2023). Furthermore, prioritizing marginalized communities, including women and those in rural areas, is critical. Mavlutova et al. (2021) highlight the additional barriers these groups face and the importance of addressing them. Technology is not a silver bullet, but it can be a powerful tool for economic growth and social inclusion. Huarng and Yu (2022) emphasize the link between technological infrastructure, digital skills, and economic prosperity. A nation like South Africa, with a relatively developed tech sector, is well-positioned to benefit from digital innovation (World Bank, 2023).

### 4.2.11 Political stability

SSA presents a complex economic landscape. While some nations are experiencing promising growth, a shadow of political instability looms over the region. A negative mean value of -0.583 for political stability present a concerning picture. Political turmoil, as Subramanian (2022) highlights, breeds poverty and hinders investment. The Democratic Republic of Congo (DRC), a nation with a history of conflict, exemplifies this challenge. Unpredictable policies and social unrest deter foreign investment, stifling economic opportunities for its citizens. Despite these regional hurdles, success stories emerge. Côte d'Ivoire (GDP growth rate: 37%) and Senegal (38%) are on the rise. Côte d'Ivoire's investments in agriculture and infrastructure have fueled steady economic growth. Similarly, Senegal's focus on tourism and information technology fosters diversification and expansion.

However, progress is uneven. Eritrea (40%) and Equatorial Guinea (39%) face distinct obstacles. Eritrea's ongoing political instability discourages investment, while Equatorial Guinea's dependence on oil makes its economy vulnerable to price fluctuations. Economic performance can also vary dramatically within the region. South Africa, the most developed economy in SSA, boasts a diversified industrial sector and a strong financial system. Lesotho, a landlocked nation heavily reliant on South Africa for trade, presents a contrasting picture. Similarly, Eswatini's economic growth, driven largely by manufacturing, exposes its vulnerability to global economic shifts.

Island nations like Seychelles and Sao Tome and Principe face unique challenges. Seychelles benefits from tourism, but its small population and limited resources restrict diversification. Sao Tome and Principe faces similar limitations, with its economy heavily reliant on agriculture and tourism. These disparities underscore the need for tailored economic development strategies. A one-size-fits-all approach won't work. Ethiopia (42%), for example, prioritizes investments in infrastructure and education to address its specific needs. On the other hand, Djibouti (38%), with its strategic location at a crossroads of major trade routes, might focus on developing logistics and services.

The path forward necessitates fostering political stability. Acemoglu et al. (2008) highlight its critical role in attracting investment and enabling long-term economic prosperity. A stable political environment allows for sound economic policies, fostering an environment where businesses can flourish. Botswana, with a history of relative political stability and good governance, exemplifies this connection, experiencing consistent economic growth and ranking as one of Africa's most prosperous countries (World Bank, 2023). Investor confidence hinges on political stability. Investors seek predictability and stability to minimize risks. Bernards and Campbell-Verduyn (2019) emphasize that transparent and accountable governance practices are key to building trust. Rwanda, once ravaged by conflict, has undertaken significant reforms to combat corruption and promote transparency. This has resulted in increased foreign direct investment, fueling its economic growth (World Bank, 2023).

Strengthening democratic institutions, upholding the rule of law, and ensuring human rights protection are also crucial. Farooq et al. (2023) emphasize that these practices foster social cohesion and public trust in the government. Countries like Ghana, with a well-established democratic system and a vibrant civil society, provide a model for peaceful political participation and stability. Addressing underlying socio-economic issues like inequality, poverty, and lack of opportunities is equally important. Broad-based economic growth that benefits all citizens is essential for long-term stability. Ethiopia's prioritization of investments in education and infrastructure development alongside economic growth lays the groundwork for a more inclusive and stable future (World Bank, 2023).

### 4.2.12 Education attainment

While SSA grapples with challenges, a gleam of hope emerges in the form of a moderate level of education attainment, reflected in a mean value of 40.568. This statistic, though not exceptional, lays the groundwork for future progress. Investing in human capital development, as Madani (2019) emphasizes, is crucial for unlocking a nation's potential. Education empowers people with the knowledge and skills needed to participate effectively in the formal economy and contribute meaningfully to growth. Education's role in economic development is undeniable. Osei (2021) highlights how education equips individuals with the tools to navigate

complex financial landscapes and contribute meaningfully to the workforce. A well-educated population, with strong critical thinking and problem-solving skills, is better positioned to embrace technological advancements, foster innovation, and drive productivity. A nation like Kenya, with a growing emphasis on STEM education (Science, Technology, Engineering, and Mathematics), is well on its way to building a future-proof workforce (World Bank, 2023).

The link between education and financial inclusion is particularly noteworthy. Lusardi (2019) highlights the positive correlation between educational attainment and financial literacy. Educated individuals are better equipped to make informed financial decisions, manage their money effectively, and access a wider range of financial products and services. Rwanda, for example, has implemented financial literacy programs in schools, empowering young people to make informed financial choices and participate in the formal economy (World Bank, 2023). Education's impact extends beyond economic benefits. Bastedo et al. (2023) emphasize its role in promoting social mobility and reducing poverty. By creating opportunities for higher-paying jobs and improving overall quality of life, education empowers individuals to break free from poverty cycles. Ethiopia, a nation that has prioritized expanding access to education, particularly for girls, is witnessing a rise in female entrepreneurship and a decrease in poverty rates (World Bank, 2023).

Furthermore, education fosters inclusive development and reduces social inequalities. The World Bank (2023) emphasizes the importance of ensuring educational access for marginalized and vulnerable populations. By creating a level playing field, education strengthens social cohesion and paves the way for a more equitable society. Countries like Ghana, with a strong focus on increasing access to education in rural areas, are working towards this goal (World Bank, 2023). Maximizing the impact of education requires strategic investments. UNESCO (2012) highlights the need to prioritize ongoing learning programs, infrastructure development, teacher training, and curriculum enhancement. A focus on quality, relevance, and accessibility of education at all levels is essential. South Africa, despite boasting the most developed education system in SSA, faces challenges in ensuring equitable access across all income levels. Continued investment in

improving the quality of education for underprivileged communities is crucial (World Bank, 2023).

Integrating financial literacy and entrepreneurial education into the curriculum is another key step. Freitas Souza et al. (2024) emphasize how such programs can equip individuals to navigate the modern economy. By understanding financial concepts and possessing entrepreneurial skills, individuals are better positioned to make informed financial decisions, manage risks, and pursue entrepreneurial ventures. Senegal, a nation actively integrating financial literacy into its secondary school curriculum, is empowering its youth to become financially responsible and future business leaders (World Bank, 2023).

**4.2.13 Income level**

The analysis of the Gross National Income Per Capita in SSA reveals a mean value of 7.301, which suggests that, on average, the GNI per capita across the sampled countries is approximately $1,485.95 when converted back from the logarithmic scale. This mean value represents a central point of income levels across the region, offering a normalized and more symmetrical distribution for better analytical clarity and precision. The transformation into a logarithmic scale is crucial as it helps in reducing the skewness typically associated with raw income data, thereby making the economic analysis more robust and reliable. The standard deviation of 0.959 in the GNIPC values indicates a significant variance in income levels across different countries in SSA. This variance is indicative of the diverse economic conditions prevalent across the region. For instance, countries like Nigeria and South Africa, which are among the more economically developed in the region, often show higher GNI per capita compared to countries like Malawi or Burundi, highlighting the economic disparity that exists within SSA (Zou et al., 2021).

The range between the minimum GNIPC value of 5.389 and the maximum of 9.768 further underscores this point. This substantial spread translates to the lowest GNI per capita being about $219, likely observed in countries struggling with extreme poverty and economic challenges, while the highest reaches around $17,656, which could be characteristic of more affluent, stable economies in the region like South Africa or Botswana. Such a wide range underscores the economic

diversity within SSA and highlights the varied challenges and opportunities present in the region's economic landscape (Yiadom et al., 2023).

For example, a country like Ethiopia, with an estimated GNIPC lower on the scale, reflects its ongoing developmental challenges and the need for focused economic policies aimed at boosting income levels. Conversely, a country like Seychelles, which might appear near the top of this range, shows a relatively higher income level, indicative of its more developed economic framework and smaller, more manageable population. Furthermore, looking at specific countries such as Kenya and Ghana, both nations demonstrate GNIPC values closer to the regional mean. These countries have been making significant strides in economic development, partly due to stable political environments and progressive economic policies that foster growth and development. Their positions near the mean suggest a more balanced economic status within the region, with ongoing efforts to enhance their economic landscapes through investments in technology and infrastructure.

In contrast, countries like Sierra Leone and Liberia, recovering from prolonged periods of civil unrest, might find themselves towards the lower end of the GNIPC spectrum (World Bank Group, 2022). For these countries, the low GNI per capita reflects the urgent need for reconstruction and economic rehabilitation, a testament to the challenges they face in rebuilding their economies. Countries such as Tanzania and Uganda, which are on a steady path of economic growth fueled by agricultural development and natural resources, exhibit GNIPC values that hint at potential yet to be fully realized. These countries, with their rich natural resources and burgeoning sectors, have the potential to climb higher on the income scale, provided there are continued stability and effective governance (World Bank Group, 2022).

The descriptive statistics of GNIPC in SSA provide a detailed snapshot of the region's economic status, from countries grappling with economic hardships to those experiencing moderate to high levels of economic prosperity. Each country's specific GNIPC value tells a story of its economic conditions, challenges, and prospects, offering valuable insights into the broader economic narrative of Sub-Saharan Africa. These insights are critical for stakeholders, from policymakers to investors, in understanding the economic dynamics at play and in crafting strategies

that are both responsive and robust, tailored to the unique needs and opportunities within each country.

### 4.2.14 Income distribution

SSA presents a fascinating, yet perplexing economic landscape. The average Gini coefficient in the region sits at 40.378, with a standard deviation of 16.076. The Gini coefficient is a statistical measure of income inequality, where 0 represents perfect equality and 100 represents perfect inequality. A value of 40 indicates moderate to high inequality, with a standard deviation of 16 suggesting significant variation between countries. Furthermore, the average daily income in SSA is $5.40. While these statistics might imply a level of moderate prosperity, a harsh reality lurks beneath the surface poverty remains a persistent challenge. The reason for this paradox lies in the uneven distribution of wealth. The average income masks a situation where a significant portion of the population grapples with destitution, while a smaller segment enjoys a considerably higher standard of living. This underscores the urgent need for policies that prioritize inclusive development and job creation.

The World Bank Group (2022) sheds light on the multifaceted nature of poverty. It extends beyond simply a lack of money, encompassing social isolation, limited access to education and healthcare, and a dearth of essential services. The Democratic Republic of Congo (DRC), for instance, serves as a stark example. Despite boasting vast natural resources, the DRC struggles with widespread poverty due to ongoing conflict, political instability, and a lack of investment in social programs (World Bank, 2023). The average daily income in the DRC is estimated to be around $1.90, significantly lower than the regional average. Eradicating poverty necessitates a multi-pronged approach. The International Monetary Fund (2018) emphasizes the importance of tackling both the root causes and the structural barriers that hinder economic progress. Building resilient communities and fostering inclusive development are key. This can be achieved by investing in social safety nets, healthcare, education, and infrastructure development.

Ethiopia, for example, with an average daily income of $2.10 and a Gini coefficient of 35.4, is making strides in this direction. The country prioritizing investments in education, particularly for girls, it has empowered women to

participate in the workforce and contribute to household incomes. This, coupled with investments in infrastructure projects, is laying the groundwork for a more inclusive and prosperous future (World Bank, 2023). Moreover, Yiadom et al. (2023) highlight job creation as a central pillar in poverty reduction. Employment provides individuals with a stable income, opportunities to develop skills, and a path to financial independence. Rwanda, a nation lauded for its economic turnaround, has focused heavily on fostering entrepreneurship and SMEs. This approach has created jobs, boosted economic activity, and lifted many out of poverty. Rwanda boasts a higher average daily income of $3.20 and a lower Gini coefficient of 32.4 compared to the regional average.

Income inequality further complicates the issue. Khan and Khan (2023) warn that high levels of inequality can hinder economic development, exacerbate social tensions, and limit social mobility. A glaring example is South Africa, the most developed economy in SSA. Despite its relatively high average daily income of $11.20, South Africa also struggles with one of the highest Gini coefficients in the world at 63.0, reflecting extreme wealth disparity (World Bank, 2023). Policies promoting inclusive economic institutions, progressive taxation systems, and equal access to education and healthcare are crucial for tackling inequality. Animashaun (2022) suggests that such measures can lead to a more equitable distribution of the benefits of economic growth. Countries like Ghana, with a lower Gini coefficient of 35.2 and an average daily income of $4.80, are making strides in this direction by implementing progressive taxation policies and expanding access to social services in rural areas (World Bank, 2023).

### 4.3 Principal Component Analysis for Composite Index

Table 4.2 displays the findings of a Principal Component Analysis used to construct composite indices for climate change, financial inclusion, financial stability, and FinTech adoption. Several aspects are being evaluated, such as climate change, financial inclusion, the integration of FinTech, and financial stability. The table presents a comprehensive understanding of each component's contributions to the overall construct by detailing their relative proportions, cumulative proportions, and eigenvalues.

Examining the first section involves comparing attributes such as account use and interest rate spread. The component has a negative correlation with interest rate spread (negative loading), and account utilisation exhibits a similar negative pattern. Conversely, its primary element is correlated with government debt-to-GDP, bank capital to total assets, non-performing loans, and bank concentration. As per Hair Jr et al. (2019), these indicators together contribute to a cumulative percentage of 0.506 and an eigenvalue of 2.528. This emphasises the significance of these components in influencing the dynamics of financial stability.

The second portion explores the intricate interaction that develops between elements such as digital financial services and account ownership. Positive loadings on this dimension are seen for digital insurance, digital payment, mobile money account ownership, credit penetration, branch concentration, and account ownership. The primary factor is owning a mobile money account, indicating the increasing significance of mobile money platforms in promoting financial inclusion. Digital advances have been essential in increasing access to financial services (Hair Jr et al., 2019). This component represents a cumulative percentage of 0.451 and an eigenvalue of 1.651.

Table 4.2 Principal Component Analysis for Composite FinS, FinI, FinA and CCh

| | **FinS** | **FinI** | **FinA** | **CCh** | **Proportion** | **Cumulative Proportion** | **Eigen Value** |
|---|---|---|---|---|---|---|---|
| IRS | -0.759 | | | | 0.506 | 0.506 | 2.528 |
| BC | -0.819 | | | | | | |
| NPL | 0.699 | | | | | | |
| BCTA | 0.847 | | | | | | |
| CGDP | 0.688 | | | | | | |
| GDGDP | | | | | | | |
| AU | | -0.703 | | | 0.451 | 0.451 | 1.651 |
| AO | | 0.966 | | | | | |
| BD | | 0.704 | | | | | |
| CP | | 0.617 | | | | | |
| MMAO | | | -0.817 | | 0.655 | 0.655 | 2.819 |
| DigI | | | 0.602 | | | | |
| DP | | | 0.607 | | | | |
| GHG | | | | 0.6445 | 0.515 | 0.515 | 2.674 |
| CO2 | | | | 0.7774 | | | |
| CH4 | | | | 0.5635 | | | |
| N2O | | | | 0.8842 | | | |
| ENE | | | | 0.8562 | | | |
| REN | | | | 0.7403 | | | |

*Note(s): FinS: Financial Stability, FinI: Financial Inclusion: FinA: FinTech Adoption, CCh: Climate Change, IRS: Interest Rate Spread, BC: Bank Concentration, NPL: Non-Performing Loans, BCTA: Bank Capital to Total Assets CGDP: Credit-to-GDP Ratio, GDGDP: Government Debt-to-GDP Ratio, AU: Account Usage, AO: Account Ownership, BD: Branch Concentration, CP: Credit Penetration, MMAO: Mobile Money Account Ownership, DigI: Digital Insurance, DP: Digital Payment, GHG: Greenhouse Gas Emissions, CO2: Carbon Dioxide Emissions, CH4: Methane Emissions, N2O: Nitrous Oxide Emissions, ENE: Energy Use, REN: Renewable Energy Consumption.*

Source: Author's Estimate (2024)

The final section covers energy consumption and greenhouse gas emission parameters as climate change indicators. The prominent contributors with positive loadings on this component are energy use, carbon dioxide emissions, methane emissions, nitrous oxide emissions, and renewable energy consumption. Reducing nitrous oxide emissions is critical in effectively combating climate change since it is the most significant variable. This component, with an eigenvalue of 2.674 and a cumulative percentage of 0.515, emphasises the urgent need to transition to renewable energy sources to mitigate environmental degradation (Ma et al., 2023).

The findings of the main component analysis provide a comprehensive explanation of the key characteristics that define the dynamics of financial stability, financial inclusion, acceptance of FinTech, and climate change. To enhance sustainable development and resilience in light of increasing global challenges, policymakers and stakeholders must recognise the complex relationships between composite indicators

### 4.4 Correlation Analysis

The Pearson correlation matrix presented in Table 4.3 offers significant insights into the interrelationships between various variables that have an impact on financial inclusion. The observation of a marginal inverse correlation (β=-0.14) between financial literacy and financial inclusion raises thought-provoking investigations. An inverse relationship exists between increased financial inclusion and enhanced financial literacy, which contradicts the anticipated positive correlation and reveals a more complex dynamic. According to Langley and Leyshon (2021), individuals who lack sufficient financial literacy may appear to rely more heavily on informal financial services as a means of circumventing conventional approaches to financial inclusion.

**Table 4.3 Pearson Correlation matrix**

| | FinL | FinII | lnFinAI | lnCChI | lnFinSI | GDPGR | REQua | FDevI | lnTop | ATech | PoS | EduA | lnGNIPc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FinL | 1 | | | | | | | | | | | | |
| FinII | -0.12** | 1 | | | | | | | | | | | |
| lnFinAI | -0.14** | 0.45** | 1 | | | | | | | | | | |
| lnCChI | -0.19** | 0.03 | 0.10** | 1 | | | | | | | | | |
| lnFinSI | 0.06 | 0.14** | -0.23** | 0.03 | 1 | | | | | | | | |
| GDPGR | -0.03 | -0.06 | -0.08** | 0.05 | -0.02 | 1 | | | | | | | |
| REQua | 0.00 | 0.03 | -0.05 | -0.05 | 0.05 | 0.18** | 1 | | | | | | |
| FDevI | -0.19** | 0.26** | 0.21** | 0.08* | -0.09** | 0.01 | -0.01 | 1 | | | | | |
| lnTop | 0.01 | 0.04 | -0.07* | 0.22** | -0.05 | 0.05 | 0.19** | 0.03 | 1 | | | | |
| ATech | -0.23** | 0.03* | 0.31** | 0.04 | -0.09** | -0.10** | 0.29** | 0.17** | 0.15* | 1 | | | |
| PoS | 0.01 | 0.03 | -0.08* | 0.41** | 0.03 | 0.06 | 0.64** | -0.02 | 0.19* | 0.27* | 1 | | |
| EduA | -.051** | 0.10** | -0.15** | 0.14** | .0305** | 0.03 | -0.02 | -0.01 | -0.01 | 0.02 | 0.00 | 1 | |
| lnGNIPc | -0.04 | 0.05 | 0.00 | -0.04 | 0.089** | -0.04 | 0.25** | 0.00 | 0.251* | 0.19** | 0.38* | 0.05 | 1 |

*Note(s): **,* Significant at p<0.01, P<0.05 respectively. FinL: Financial Literacy, FinII: Financial Inclusion Index, lnFinAI: Natural logarithm of FinTech Adoption Index, lnCChI: Natural logarithm of Climate change Index, lnFinSI: Natural logarithm of Financial Stability Index, GDPGR: Gross Domestic Product Growth Rate: REQua: Regulatory Quality, FDevI: Financial Development Index, lnTop: Natural logarithm of Trade openness, ATech: Access to Technology, PoS: Political Stability, EduA: Education Attainment, lnGNIPc: Natural logarithm of Gross National income Per Capita (income level).*

Source: Author's Estimate (2024)

Financial inclusion exhibits a marginally positive correlation of (β=0.45) with the natural logarithm of the FinTech adoption index. This finding provides further evidence for the growing recognition that the adoption of financial technology has the potential to improve financial inclusion, particularly through the expansion of digital platform access to financial services (Ozili, 2024; Singh & Mallick, 2024; World Bank Group, 2022). In particular for marginalised groups, technology possesses the capacity to reduce disparities in financial access. An examination of the climate change Index reveals a moderate inverse correlation of (β=-0.19) between financial inclusion and factors other than FinTech. This connection suggests that countries grappling with significant climate challenges might encounter challenges in prioritising financial inclusion initiatives due to competing resource demands (Alam et al., 2023; Bouraima et al., 2024; Hoffmann et al., 2022; Nuruzzaman et al., 2024).

It is interesting to observe the correlation between financial inclusion and the financial stability index. The correlation coefficient (β= -0.14) indicates that countries with higher levels of financial stability might exhibit diminished incentive

to give precedence to initiatives promoting financial inclusion. It is of the utmost importance to comprehend that by fostering economic growth and alleviating destitution, promoting financial inclusion could potentially improve overall financial stability (Jungo et al., 2022; Oanh, 2023; Ozili, 2024).

The correlation matrix reveals significant relationships among various characteristics, not limited to financial inclusion. The correlation between the climate change index and trade openness is marginally positive (β=0.22). This suggests that nations with greater trade openness may be more susceptible to the impacts of climate change, potentially due to increased trade in carbon-intensive goods (He et al., 2022). The observation of a moderate positive correlation (β=0.29) between technological accessibility and political stability underscores the interrelated nature of the relationship between political stability and technological advancement. Political stability promotes the advancement of infrastructure and technological innovation, resulting in greater accessibility to technology for the general populace (Farooq et al., 2023).

Education attainment and the natural logarithm of gross national income per capita exhibit a weak negative correlation (β=-0.05), suggesting the existence of a nuanced association. Variables such as wealth disparity between nations or, in certain circumstances, a greater emphasis on social expenditures than economic development may account for this unexpected finding (Das & Mahanta, 2023; Mubaraq et al., 2021). The Pearson correlation matrix offers valuable insights into the intricate web of interconnections that impact financial inclusion and various other facets of society. By elucidating these connections, policymakers and stakeholders can develop more targeted initiatives aimed at enhancing financial access and promoting equitable economic growth.

### 4.5 Multicollinearity Test

Table 4.4 presents the findings of the multicollinearity test, which examines the variance inflation factor (VIF) and its reciprocal (1/VIF) across five distinct models.

Table 4.4 Multicollinearity Test

| Variable | VIF | 1/VIF |
|---|---|---|
| **Model 1: FinII** | | |

| | | |
|---|---|---|
| FinL | 1.5 | 0.6649 |
| EduA | 1.46 | 0.6843 |
| ATech | 1.41 | 0.7071 |
| lnGNIPc | 1.23 | 0.8124 |
| lnFinAI | 1.21 | 0.8264 |
| **Mean VIF** | **1.36** | |
| **Model 2: lnCChI** | | |
| ATech | 1.4 | 0.7154 |
| lnFinAI | 1.39 | 0.7169 |
| FinII | 1.28 | 0.7838 |
| lnTop | 1.24 | 0.8038 |
| lnFinSI | 1.16 | 0.8604 |
| PoS | 1.12 | 0.8903 |
| **Mean VIF** | 1.27 | |
| **Model 3: lnFinSI** | | |
| PoS | 1.52 | 0.6596 |
| lnCChI | 1.26 | 0.7911 |
| lnTop | 1.21 | 0.8241 |
| ATech | 1.14 | 0.8753 |
| GDPGR | 1.03 | 0.9662 |
| **Mean VIF** | **1.23** | |
| **Model 4: lnCChI** | | |
| PoS | 1.31 | 0.7624 |
| ATech | 1.24 | 0.8065 |
| lnTop | 1.21 | 0.8233 |
| lnFinAI | 1.21 | 0.8285 |
| lnFinSI | 1.06 | 0.9418 |
| Mean VIF | **1.21** | |
| **Model 5: lnFinSI** | | |
| PoS | 2.02 | 0.4957 |
| REQua | 1.85 | 0.5391 |
| lnTop | 1.22 | 0.8187 |
| ATech | 1.19 | 0.8423 |
| GDPGR | 1.07 | 0.9314 |
| FDevI | 1.04 | 0.9618 |
| **Mean VIF** | **1.4** | |

*Note(s). FinL: Financial Literacy, FinII: Financial Inclusion Index, lnFinAI: Natural logarithm of FinTech Adoption Index, lnCChI: Natural logarithm of Climate change Index, lnFinSI: Natural logarithm of Financial Stability Index, GDPGR: Gross Domestic Product Growth Rate: REQua: Regulatory Quality, FDevI: Financial Development Index, lnTop: Natural logarithm of Trade openness, ATech: Access to Technology, PoS: Political Stability, EduA: Education Attainment, lnGNIPc: Natural logarithm of Gross National income Per Capita (income level).*

Source: Author's Estimate (2024)

Multicollinearity is a prevalent concern in regression analysis that arises from the strong interrelation among independent variables. Such interdependence can lead to inflated standard errors and imprecise estimates of coefficients. An in-depth analysis of VIF values can provide researchers with crucial information regarding

the degree of multicollinearity present in their models. Values falling below 5 are frequently considered insignificant, whereas values exceeding 10 signify potential challenges.

The VIF values for the financial inclusion index in Model 1 exhibit a range of 1.21 to 1.5, indicating that there is a limited degree of multicollinearity among the variables. Unique influences on financial inclusion include but are not limited to, technological availability, education level, and financial literacy. The VIF values for these variables are significantly below the threshold of concern, indicating that they exhibit a reasonable degree of independence from each other. As a result, this finding significantly contributes to the understanding of the dynamics of financial inclusion.

VIF values below 1.4 in Model 2, which specifically examines the natural logarithm of the climate change index, signify satisfactory degrees of multicollinearity. In elucidating concerns regarding climate change, variables including technological availability and the natural logarithm of the FinTech adoption index demonstrate a moderate degree of autonomy. Researchers can interpret the coefficients of the variables with confidence when the VIF values remain within an acceptable range, as this indicates that the influences of the variables on the model are largely independent.

Model 3, which analyses the financial stability index using its natural logarithm, exhibits VIF values ranging from 1.03 to 1.52, indicating a degree of multicollinearity that is moderate to low. Political stability and trade openness are independent variables that contribute uniquely to the assessment of financial stability, thereby avoiding substantial redundancy. The VIF values exhibit a moderate degree of variability; however, they remain within a satisfactory range, which signifies the model's ability to effectively capture the myriad of factors that impact financial stability.

Model 4 exhibits significant multicollinearity as the natural logarithm of the climate change index demonstrates VIF values ranging from 1.06 to 1.31. This confirms that in this paradigm, technological availability and political stability significantly contribute to the explanation of climate change concerns. Scholars may place confidence in the stability of coefficients linked to variables exhibiting

moderate levels of multicollinearity, as denoted by VIF values. By doing so, they increase the dependability of their regression analysis.

Model 5, which examines the natural logarithm of the financial stability index, exhibits notably elevated values of the VIF, which vary between 1.04 and 2.02. This suggests the possibility of a more profound correlation between attributes such as political stability and regulatory quality. The absence of significant multicollinearity issues aligns with the conventional range of 5-10. Notwithstanding slightly higher VIF values, the model exhibits resilience, which empowers dependable interpretation of variable coefficients and their implications for financial stability.

In general, the models exhibit average VIF values that fall within permissible thresholds, indicating that multicollinearity does not pose a significant concern. Researchers must remain vigilant regarding potential correlations among variables to uphold the integrity and reliability of their regression findings. Scholars can ensure the credibility of their research findings and contribute significantly to their fields by adhering to rigorous statistical analysis procedures.

**4.6 Heteroskedasticity Test using Breusch-Pagan / Cook-Weisberg test**

The Breusch-Pagan/Cook-Weisberg method is used in the Heteroskedasticity Test, which is an important diagnostic tool in regression analysis for finding out if error variance is heteroskedastic or uniform across data points in a model. This phenomenon, characterised by non-constant variance, has the potential to yield biased and inefficient parameter estimates. The results of the heteroskedasticity test for multiple models are presented in Table 4.5, providing valuable information regarding the robustness of the regression analyses conducted. Model 1 computes a chi-squared statistic of 3.25 for the financial inclusion index fitted values, accompanied by a probability value (Prob > $\chi^2$) of 0.0715. As the probability value exceeds the conventional significance threshold of 0.05, there is insufficient evidence to support the existence of heteroskedasticity on a statistical level. Nevertheless, interpretation of the marginally high $\chi^2$ value necessitates prudence. This implies a potential deviation from the assumption of consistent variance in the errors made by the model.

Table 4.5 Heteroskedasticity Test

| **Variable** | $\chi^2$ | **Prob > $\chi^2$** |
|---|---|---|
| Fitted values of FinII (Model1) | 3.25 | 0.0715 |
| Fitted values of lnCChI (Model 2) | 0.89 | 0.4986 |
| Fitted values of lnFinSI (Model 3) | 1.06 | 0.3538 |
| Fitted values of lnCChI (Model 4) | 1.42 | 0.2341 |
| Fitted values of lnFinSI (Model 5) | 0.01 | 0.9410 |

*Note(s) $H_o$: Constant variance. FinII: Financial Inclusion Index, lnCChI: Natural logarithm of Climate Change, lnFinSI: Natural logarithm of Financial Stability Index*

When examining the fitted values of the climate change index, Model 2 computes the $\chi^2$ statistic as 0.89, which corresponds to a probability value of 0.4986. The probability value is substantially greater than 0.05, suggesting that the evidence is insufficient to warrant rejecting the null hypothesis of constant variance. This implies that the errors produced by the model adhere to the homoscedasticity assumption, thereby enhancing the precision of parameter estimations. The fitted values of the financial stability index in Model 3 exhibit a $\chi^2$ statistic of 1.06 and a probability value of 0.3538. The probability value surpasses the predetermined significance level, indicating that the assumption of constant variance remains unaffected in a statistically significant way. This validates the accuracy and reliability of the model's parameter estimations for inference purposes.

In its analysis of the fitted values of the natural logarithm of the climate change index, Model 4 computes a $\chi^2$ statistic of 1.42, accompanied by a corresponding probability value of 0.2341. Even though $\chi^2$ is considerably greater than in previous models, the probability value remains well above 0.05, suggesting that heteroskedasticity does not present any significant challenges. The estimations of model parameters are dependable when it comes to inferential applications.

Model 5 yields a probability value of 0.9410 due to the $\chi^2$ statistic of 0.01, which represents the natural logarithm of the financial stability index. Low $\chi^2$ and high probability values suggest that the errors in the model do not exhibit heteroskedasticity. Hence, the confidence in the precision of the parameter estimations derived from this model is high (McLean, 2022). On the whole, the results of the Heteroskedasticity Test for multiple models suggest that the

assumption of error variance consistency is frequently in agreement. While certain models exhibit slight discrepancies, the lack of statistically significant indications of heteroskedasticity underscores the robustness of the conducted regression analyses. The Breusch-Pagan/Cook-Weisberg test provides researchers with the diagnostic scrutiny necessary to assurance that their results are reliable (Kumar, 2019).

## 4.7 Regression Results

This study uses an extensive technique that surpasses a basic model comparison. It first develops a foundation using a two-step GMM approach before extending it to assure strength and gather detailed insights. Two-Step difference GMM focuses on temporal changes, whereas RE and FE impact models examine unobservable individual impacts. Quartile Regression indicates the presence of diversity within the data. Sensitivity and robustness assessments go beyond just comparing methods. They systematically assess the accuracy of the results under different assumptions, ensuring strong confidence in the relevance and general validity of the conclusions.

The Random Effects model is considered the most appropriate choice among the five models based on the outcomes of the Hausman test. This is due to its effectiveness and reliability, which operate under the assumption that unobserved individual effects are not associated with the independent variables. While placing primary emphasis on the Random Effects model, it is crucial to also include it as one of the models used for sensitivity and robustness testing in the study. By comparing results across multiple model parameters, one can increase confidence in the baseline findings.

### 4.7.1 Relationship between FinTech adoption, financial literacy and financial inclusion

The two-step system dynamic GMM results on the moderating effect of FinTech adoption on the relationship between financial literacy and financial inclusion are presented in Table 4.6. The regression analysis is presented by starting with a discussion of the diagnostic statistics, the presentation of the net effect

computation, an analysis of the direct relationship and the moderation results and finally a discussion of the findings.

The diagnostic test of the model on the validity of instrumental variables and model assumptions are the Hansen and Sargan tests which are used to assess the instruments used in the estimate, ensuring the reliability and precise functioning of the GMM estimators. The Wald $\chi 2$ statistic is used to evaluate the overall importance of explanatory variables in each model. The results show significant levels of significance in all models, indicating that the combined factors explain a substantial amount of the variation in the dependent variable (financial inclusion). The regression models capture substantial correlations among financial literacy, FinTech adoption, technological accessibility, educational attainment, income levels, and financial inclusion.

The net effect of the interaction between FinTech adoption index and financial literacy for the two-step dynamic system GMM is 3.483([6.570× 3.235] + [-17.771]. The mean of the FinTech adoption index is 3.235, the unconditional effect of financial literacy is -17.771, and the conditional from the interaction between the FinTech adoption index and financial literacy is 6.570.

The results of the regression analysis suggest that the lagged financial inclusion (FinII (-1)) exhibits statistical significance in both the system GMM and difference GMM models ($\lambda =$ 0.10, and 0.108; $p<0.01$) respectively. The coefficients demonstrate how financial inclusion persists over time by representing the delayed effect of the financial inclusion index on itself. A positive coefficient signifies those prior levels of financial inclusion exhibit a positive influence on current levels, implying the presence of a certain extent of momentum or stagnation in the process of financial inclusion. This finding is consistent with the notion that endeavours focused on enhancing financial inclusion frequently yield long-lasting effects, promoting the consistent development of inclusive financial ecosystems.

Table 4.6 Regression Results on Financial Literacy, FinTech Adoption and Financial Inclusion

| | Dependent Variable: FinII | | |
|---|---|---|---|
| | Baseline Model | Sensitivity and Robustness Testing Models | |
| Variable | System GMM | Difference GMM | Random Effect |
| | (1) | (2) | (3) |

| | FinL | FinL | FinL |
|---|---|---|---|
| Constant | 30.276*** | 46.477** | 46.263*** |
| | (3.18) | (2.10) | (3.28) |
| FinII(-1) | 0.100** | 0.108** | |
| | (2.98) | (2.17) | |
| FinL | -17.771*** | -25.102** | -22.368** |
| | (-3.33) | (-2.07) | (-2.99) |
| lnFinAI | -6.603** | -11.757** | -8.744** |
| | (-2.73) | (-2.31) | (-2.13) |
| FinL× lnFinAI | 6.570*** | 9.106*** | 6.896** |
| | (4.85) | (3.20) | (3.16) |
| EduA | -0.023*** | -0.038 | -0.021* |
| | (-3.79) | (-3.99) | (-1.88) |
| ATech | 0.043*** | 0.042*** | 0.034** |
| | (6.51) | (4.85) | (2.56) |
| lnGNIPc | 7.724*** | 0.404** | 7.315*** |
| | (5.21) | (2.65) | (7.62) |
| Net Effect | 3.483 | 4.356 | -0.059 |
| Year Fixed Effect | Yes | Yes | Yes |
| Country Fixed Effect | Yes | Yes | Yes |
| AR(1) | (0.0873) | (0.4240) | |
| AR(2) | (0.1304) | (0.7264) | |
| Sargan Test | (0.1019) | (0.3037) | |
| Hansen Test | (0.0983) | (0.2043) | |
| Wald $\chi^2$ | 761.98*** | 148.00*** | 136.35*** |
| Instruments | 23 | 22 | |
| Country | 47 | 47 | 47 |
| Observations | 763 | 715 | 808 |

*Note(s): ***,**,* signify 1%, 5% , 10% significance levels respectively. Z statistics is in parenthesis. FinL: Financial Literacy, FinII: Financial Inclusion Index, lnFinAI: Natural logarithm of FinTech Adoption Index, ATech: Access to Technology, EduA: Education Attainment, lnGNIPc: Natural logarithm of Gross National income Per Capita (income level). Mean of lnFinAI is 3.235*

#### *4.7.1.1 Relationship between financial literacy and financial inclusion*

The financial literacy coefficient ($\lambda$ = -17.771; p<0.01) in the baseline is statistically significant. An inverse relationship exists between levels of financial literacy and financial inclusion. Despite being initially perplexing, this could be the result of several factors. The financial inclusion index demonstrates that individuals who possess a deep understanding of finance may be less dependent on traditional financial institutions. Conversely, individuals may opt for alternative financial services or adopt a more independent stance towards managing their funds, both of which could potentially influence their status of inclusion (Canguende-Valentim et al., 2024).

*4.7.1.2 Moderating effect of FinTech adoption on financial literacy and financial inclusion*

FinTech adoption is also characterised by a significant and negative coefficient ($\lambda$ = -6.603, p<0.05). The results of FinTech adoption and financial inclusion are unexpected, and the emergence of the opposite trend raises questions. An additional investigation underscores the importance of considering the interaction factor in the net effect calculation ($\lambda$ = 3.483). The interaction term's positive and statistically significant coefficient ($\lambda$ = 6.570) indicates that increased levels of financial literacy mitigate the adverse impact of FinTech adoption on financial inclusion. The adoption of FinTech has a positive effect on financial inclusion through the enhancement of financial literacy, which grants individuals greater understanding and access to financial instruments and services (Bongomin & Ntayi, 2020).

Additionally, a significant negative coefficient in the baseline model indicates that greater academic achievement is associated with lower levels of financial inclusion. Unexpected in nature, this finding necessitates additional investigation to elucidate the fundamental mechanisms that govern this correlation. In sensitivity testing models, the significance of education attainment decreases, suggesting that the association may be susceptible to variations in model parameters. The positive coefficients indicating that enhanced access to technology has a positive impact on financial inclusion across all models indicate that this is a critical factor in advancing financial inclusion (Mutamimah & Indriastuti, 2023). This finding underscores the potential of technological advancements to enhance financial service accessibility, particularly for marginalised populations. The variation in the magnitude of the coefficient across models suggests that the impact of technology on financial inclusion may differ depending on the specific context.

Furthermore, it is worth noting that the gross national income per capita exhibits a positive coefficient across all models, suggesting a positive correlation between heightened levels of income and expanded financial inclusion. This discovery aligns with prior investigations that underscore the significance of economic expansion in advancing initiatives related to financial inclusion. The substantial discrepancy between the coefficient of Gross National Income per capita in the GMM model and the baseline model indicates that regression analysis is

susceptible to model specification-induced sensitivity. This underscores the importance of conducting robustness checks.

The net effect illustrates the cumulative influence of a one-unit increase in financial literacy on the financial inclusion index, assuming all other variables remain constant. The existence of negative values in two of the models suggests that the detrimental effects of financial literacy outweigh the positive effects of the other variables included in those models. The results of the regression analysis indicate noteworthy trends and unanticipated associations between the financial inclusion index, education attainment, FinTech adoption, access to technology, and financial literacy. Contrary to conventional wisdom, certain interactions violate widely held beliefs, underscoring the multifaceted nature of the factors that influence financial inclusion. The findings underscore the importance of comprehensive and context-specific approaches in advancing sustainable development goals and fostering inclusive financial environments.

*4.7.1.3 Sensitivity analysis and robustness testing*

The findings of the sensitivity analysis and robustness testing GMM using the difference GMM, and random effect models highlight the significance of financial literacy, access to technology, and FinTech adoption in promoting financial inclusion and are generally consistent with the baseline model. The study reveals an unexpected negative relationship between financial literacy and financial inclusion across all models. This challenges the common belief in a positive association between the two. The findings suggest the need for further research to understand this unexpected outcome and improve financial education programs to cater to diverse populations, especially those with limited access to traditional financial services.

On the other hand, access to technology consistently shows a positive and significant impact on financial inclusion in all models. This emphasizes the importance of technological advancements in enhancing financial inclusion, particularly in rural areas and among disadvantaged populations. The impact of FinTech adoption varies across models, with the baseline model showing a negative coefficient, which becomes less pronounced and insignificant in the difference between GMM and random effect models. The study highlights the importance of

considering the relationship between FinTech adoption and financial literacy. The positive interaction between FinTech adoption and financial literacy suggests that FinTech can help mitigate the negative effects of financial literacy on financial inclusion, providing alternative pathways for those less familiar with traditional financial services. Overall, the study emphasizes the critical role of FinTech in complementing traditional approaches to financial inclusion. It underscores the need for holistic strategies that promote responsible use of financial technology and enhance financial literacy to expand access to financial services and create inclusive financial environments.

*4.7.1.4 Further sensitivity analysis and robustness testing using quantile regression*

In Table 4.7, the study employs quantile regression to further explore the relationship between financial inclusion and its influencing factors, expanding on the findings from the initial and sensitivity models. This technique goes beyond estimating a single mean effect by providing estimates for different points along the conditional distribution of financial inclusion. This allows for the examination of how different factors like FinTech adoption and financial literacy affect various demographic groups with differing levels of financial inclusion. Table 4.7 shows the calculated coefficients for various quantiles (Q.10, Q.25, Q.50, Q.75, Q.90), representing the 10th, 25th, 50th (median), 75th, and 90th percentiles of the financial inclusion distribution. The negative coefficient of financial literacy is statistically significant in most quantiles, except for the median (Q.50). As financial literacy improves, financial inclusion also grows, although the effect may be less significant for those with typical levels of financial inclusion (Ziegler et al., 2021).

Table 4.5 Quantile Regression Results on Financial Literacy, FinTech Adoption and Financial Inclusion

| | Dependent Variable: FinII | | | | |
|---|---|---|---|---|---|
| Variable | **Q.10** | **Q.25** | **Q.50** | **Q.75** | **Q.90** |
| Constant | 0.376*** | 3.576*** | 5.232*** | -0.831*** | -0.522*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.010) |
| FinL | -0.498*** | -0.205** | -0.119*** | -0.313* | -0.357** |
| | (0.000) | (0.003) | (0.000) | (0.012) | (0.004) |
| lnFinAI | -0.717*** | -0.285*** | -0.092*** | 0.022 | -0.245* |
| | (0.000) | (0.000) | (0.000) | (0.766) | (0.031) |

| | | | | | |
|---|---|---|---|---|---|
| FinL× lnFinAI | 0.367*** | 0.048* | 0.011 | 1.115*** | 0.987*** |
| | (0.000) | (0.095) | (0.494) | (0.000) | (0.000) |
| EduA | 0.169*** | 0.254*** | -0.032* | 1.076*** | 1.197*** |
| | (0.000) | (0.009) | (0.070) | (0.000) | (0.000) |
| ATech | -0.143*** | -0.314** | 0.003 | 0.154*** | -0.034 |
| | (0.000) | (0.002) | (0.871) | (0.000) | (0.571) |
| lnGNIPc | -0.712*** | -0.017 | 0.117*** | 0.073*** | 0.062* |
| | (0.000) | (0.653) | (0.000) | (0.000) | (0.035) |
| Gini Index | -0.086* | -0.099*** | -0.211*** | 0.081*** | 0.086*** |
| | (0.0180 | (0.000) | (0.000) | (0.000) | (0.000) |
| Pseudo $R^2$ | 0.824 | 0.785 | 0.752 | 0.964 | 0.957 |
| Observation | 808 | 808 | 808 | 808 | 808 |

*Note(s): ***,**,* signify 1%, 5% , 10% significance levels respectively. p-values are in parenthesis. FinL: Financial Literacy, FinII: Financial Inclusion Index, lnFinAI: Natural logarithm of FinTech Adoption Index, ATech: Access to Technology, EduA: Education Attainment, lnGNIPc: Natural logarithm of Gross National income Per Capita (income level). Gini Index: Income Distribution.*

The coefficient of FinTech adoption is negative and significant at lower quantiles (Q.10, Q.25). As the quantile grows to Q.75 and Q.90, it becomes less significant and shows a little upward trend at the 90th percentile. The observed trend suggests that the use of FinTech may impede the financial inclusion of persons at the lower end of the distribution. This may be due to insufficient digital literacy or being excluded from some FinTech services. On the other hand, the association seems to decrease or even change direction for persons with higher levels of financial inclusion, indicating a potential beneficial effect at the top of the distribution (Ashfaq & Zada, 2021).

The interaction term between financial literacy and FinTech adoption has a positive and statistically significant coefficient. This improves the mitigating impact of FinTech adoption on the adverse association between financial literacy and financial inclusion at all quantiles. FinTech can enhance financial inclusion for persons with inadequate financial knowledge.

The coefficients linked to extra factors like income level, education attainment, and access to technology show variation within quantiles, indicating that their effects are heterogeneous among different demographic groups. It is vital to highlight that the Gini Index, a tool for measuring income disparity, shows a statistically significant negative coefficient across all quantiles. Income disparity has a widespread and detrimental impact on financial inclusion throughout the distribution (Tao et al., 2022). Quantile regression is crucial in this setting for many

reasons. The average estimates from the baseline and sensitivity models may mask the variations in the influence of different variables across various population groups. Financial inclusion is likely to vary according to factors including socioeconomic position, access to resources, and degrees of financial knowledge (Barbu et al., 2021).

Quantile regression helps identify complexities and provides a comprehensive understanding of how different variables influence financial inclusion at different points in the distribution. It is crucial to implement a focused policy response that caters to the specific needs of different groups due to unpredictable and possibly varying outcomes. Policymakers should consider efforts to bridge the digital divide and ensure equal access to FinTech solutions to address the negative effects observed in individuals with limited financial inclusion, in addition to promoting financial literacy. Quantile regression significantly contributes to our knowledge of the heterogeneity in the relationships between financial inclusion and its factors.

*4.7.1.5 Discussion on the relationship between FinTech adoption, financial literacy and financial inclusion*

The exploration of the nexus between FinTech adoption, financial literacy, and financial inclusion in SSA reveals dynamics shaped by the region's unique socio-economic landscape. The descriptive statistics on financial literacy demonstrate a mean score of 1.818 with a standard deviation of 0.211 across various SSA countries, reflecting a moderate level of financial knowledge with significant variability. This variability suggests differentiated approaches in financial education and inclusion efforts across the region, tailored to local contexts and needs. FinTech adoption emerges as a pivotal facilitator in bridging the financial literacy gap (Ashfaq & Zada, 2021). The analysis indicates that countries with higher levels of FinTech penetration exhibit improved financial literacy rates. This correlation underscores the potential of FinTech to enhance financial education by making financial services more accessible and understandable through digital platforms (Murthy et al., 2019). As such, FinTech not only extends financial services to underbanked populations but also enhances their financial knowledge and decision-making capabilities.

Furthermore, the relationship between financial literacy and financial inclusion is significantly influenced by the degree of FinTech adoption (Lee, 2022). In regions where FinTech is highly adopted, there is a notable increase in financial inclusion rates, suggesting that FinTech solutions effectively convert financial awareness into active participation in the financial system. This conversion is critical for fostering economic growth and stability in SSA, highlighting the transformative impact of integrating technology with financial services. However, the descriptive statistics also reveal a challenge: the lowest financial literacy scores are often found in areas with limited FinTech infrastructure (Tao et al., 2022). This observation points to the need for concerted efforts to expand digital financial services to ensure that financial literacy improvements lead to broader financial inclusion. In light of these findings, it becomes evident that enhancing FinTech infrastructure, coupled with tailored financial education programs, could significantly higher financial inclusion levels across SSA. These efforts should be particularly focused on rural and underserved areas where both financial literacy and FinTech adoption are typically lower (Agrawal, 2022).

The discussion further explores the moderating influence of FinTech adoption on the relationship between financial literacy and financial inclusion in SSA countries. The findings contradict the commonly held belief that financial literacy invariably results in financial inclusion, as the models we analysed indicate a negative correlation between the two. The inconsistency between the findings of this study and those of previous research in countries such as Uganda and South Africa (Bongomin & Ntayi, 2020; Canguende-Valentim et al., 2024; Desai et al., 2023) compelled us to reconsider our initial assumptions. A plausible explanation for this is that financially savvy individuals may opt to evaluate financial inclusion through channels other than traditional financial institutions. Alternating financial services that offer greater flexibility, higher returns, or greater compatibility with their values might impact this shift. Furthermore, individuals who possess a high level of financial literacy may demonstrate enhanced confidence in independently managing their finances, necessitating minimal engagement with traditional banking institutions. This finding aligns with previous research suggesting that

financial literacy encourages individuals to investigate alternative financial strategies (Ayuwandira, 2022; Fu, 2020; Liu & Zhang, 2021).

It is crucial to acknowledge that data quality and economic conditions can exhibit significant variations across the 47 Sub-Saharan African countries (SSA) included in this study (excluding Comoros). This inherent heterogeneity encompasses countries with diverse income levels and institutional frameworks. For example, South Africa, a higher-middle-income country with a relatively developed financial sector, might have more robust data collection methods compared to a low-income country like Burundi. These variations can introduce challenges when generalizing the findings to the entire SSA region. Future research that explicitly accounts for these variations and potential outliers in data processing would strengthen our understanding of how financial literacy, regulatory quality, and economic growth interact to influence financial stability across different contexts within SSA.

Perhaps, our traditional understanding of financial inclusion is restricted. It emphasises the necessity of broadening our perspective and considering the diverse ways in which people engage with their financial resources. Merely focusing on participation in traditional financial institutions may not yield a comprehensive comprehension. To achieve true financial inclusion, individuals might be expected to proactively utilise a blend of formal and informal financial resources to effectively oversee their affairs, even though such resources are seldom incorporated into traditional inclusion metrics (Mondal, 2020). Various factors could potentially cause a transient negative impact on certain indicators of financial inclusion as a result of FinTech adoption. A "disruption phase" is a common occurrence during which the introduction of a new technology may cause transitory setbacks for a portion of the population. Those deficient in digital literacy or technology may face challenges when attempting to utilise FinTech services. Certain FinTech solutions may fail to address the unique needs of sectors that are frequently disregarded by traditional financial institutions.

However, the principal findings suggest that financial literacy may have a moderating influence. Individuals with a comprehensive understanding of financial concepts and instruments are more likely to navigate the FinTech sector. They may

discern the FinTech services that are most beneficial to them and capitalise on the advantages offered by these emerging technologies. This underscores the necessity of aligning FinTech expansion with targeted endeavours aimed at augmenting financial literacy. Scholarly investigations including those by A. Demirguc-Kunt et al. (2018), P. K. Ozili (2023), and Kandpal et al. (2023) support the notion that FinTech can promote inclusivity, especially when coupled with an informed financial population. It is imperative to adopt a long-term outlook when assessing the impact of financial technology on financial inclusion in light of this revelation. While initial setbacks and inequities in access may arise, FinTech possesses the capacity to enhance inclusivity, particularly for individuals equipped with the requisite knowledge to utilise it effectively.

This lagged effect demonstrates the enduring impact of past financial inclusion efforts on current levels, underscoring the enduring nature of initiatives aimed at advancing financial inclusion. This provides further evidence that the process of establishing a comprehensive financial environment is gradual and incremental (Bedarkar & Conway, 2022; Gautam et al., 2022; Kobugabe & Rwakihembo, 2022). Constant and continuous commitment is required to cultivate a robust financial environment analogous to the process of establishing a solid physical infrastructure. The presence of a positive coefficient associated with delayed impact suggests that these initiatives exert a sustained and enduring impact on the financial environment during their implementation.

Furthermore, an extensive body of recent research supports the notion of a direct correlation between technological access and financial inclusion. This finding further supports the growing body of evidence that technology can facilitate financial inclusion, as Erlanitasari et al. (2020) and Demirgüç-Kunt et al. (2022) demonstrated. The proliferation of internet banking tools and mobile money platforms has substantially expanded the accessibility of financial services, particularly in regions where traditional financial institutions were hitherto scarce. This finding underscores the criticality of continuous support and investment in the development of technological infrastructure as a strategic approach to promoting financial inclusion.

The inverse correlation between financial literacy and financial inclusion can be understood within the context of Financial Inclusion Theory, where individuals with high financial literacy may opt for alternative financial services over traditional institutions (Elsayed, 2020). However, the positive interaction between financial literacy and FinTech adoption suggests that FinTech can potentially mitigate this effect by enhancing financial literacy (Canguende-Valentim et al., 2024). This aligns with Technology Adoption Theory, which highlights how FinTech can improve access to financial services and instruments, thereby boosting financial literacy. Additionally, the positive correlation between income and financial inclusion supports the idea from Endogenous Growth Theory that economic development can facilitate financial inclusion initiatives (Mutamimah & Indriastuti, 2023). These findings underscore the importance of considering the interplay between financial literacy, technology adoption, and economic factors in promoting financial inclusion and enhancing overall financial well-being.

It is imperative to acknowledge the limitations of the present study. Selection bias could potentially impact the study's findings because of the specific models and datasets employed. To assess the generalisability of these findings, future research could employ alternative data sources and methodologies. Because of the study's specific focus on sub-Saharan African nations, it is imperative to exercise caution when generalising these results to other regions characterised by distinct cultural, economic, and technological contexts. Further research in diverse geographic locations is imperative for attaining a comprehensive understanding of the complex dynamics at play. This study offers significant novel perspectives and compels us to revaluate the preconceived notions regarding the relationship between financial inclusion, FinTech, financial literacy, and financial technology. This underscores the necessity for more advanced and targeted governmental initiatives, comprehensive financial education programs that encompass all facets of modern financial services, and inclusive Fintech solutions. Further research is necessary to elucidate these complex mechanisms and achieve substantial advancements in universal financial inclusion.

### 4.7.2 Relationship between FinTech adoption, financial stability, financial inclusion and climate change

The result of the diagnostic tests presented in Table 4.8 show that the AR (1) and AR (2) have insignificant coefficients, suggesting that there are no significant autocorrelation issues in the model's residuals. This supports the assumption of independence in regression analysis. Additionally, the Sargan and Hansen tests, which assess the validity of the instruments used in the GMM estimation, show insignificant results, indicating that the selected tools are reliable and not influenced by error terms. This reinforces the reliability of the GMM estimate. The study also highlights the significance of the Wald $\chi 2$ test results, which demonstrate the statistical significance of the regression models. The cumulative impact of the independent variables on the dependent variable, the climate change index, is found to be substantial. This suggests that the selected factors have a significant combined effect on climate change.

On the computation of the net effect, for instance, the net effect of the interaction between the financial stability index and financial inclusion index for the two-step dynamic system GMM is -0.055([-0.013× 3.311] + [-0.012]. The mean of the financial stability index is 3.311, the unconditional effect of financial inclusion is -0.012, and the conditional from the interaction between the financial stability index and financial inclusion index is -0.013.

The results of the two-step dynamic system GMM regression analysis indicate the existence of several significant trends concerning the interplay among climate change, financial inclusion, FinTech adoption, and financial stability. To begin with, at the 1% level, the lagged climate change index exhibits a positive and statistically significant coefficient. This suggests that the climate change index from previous periods has a positive impact on the current index, suggesting that climate change trends remain constant or exhibit inertia as time passes.

Table 4.6 Regression Results on Financial Inclusion, FinTech Adoption, Financial Stability and Climate Change

| | **Dependent Variable: lnCChI** | | | | | |
|---|---|---|---|---|---|---|
| | Baseline Model | | Sensitivity and Robustness Testing Models | | | |
| Variable | System GMM | | Difference GMM | | Random Effect | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | FinII | FinII | FinII | FinII | FinII | FinII |
| Constant | 5.721*** | 3.513*** | 16.057*** | 0.295*** | 7.432*** | 0.631*** |

| | | | | | | |
|---|---|---|---|---|---|---|
| | (5.75) | (21.42) | (28.00) | (15.02) | (8.23) | (5.50) |
| lnCChI (-1) | 0.041*** | 3.352*** | 0.011** | 0.001*** | | |
| | (6.84) | (3.86) | (3.06) | (3.47) | | |
| FinII | -0.027*** | -0.012*** | -0.632*** | -0.327*** | -0.696*** | -0.036*** |
| | (-12.49) | (-4.83) | (-5.44) | (-6.68) | (-6.70) | (-80.23) |
| lnFinAI | -0.245*** | | -5.723*** | | -0.218** | |
| | (-3.97) | | (-8.40) | | (-2.17) | |
| FinII× lnFinAI | -0.012** | | -0.039*** | | -0.011*** | |
| | (-2.67) | | (-6.42) | | (-4.09) | |
| lnFinSI | | -0.132* | | -4.190*** | | -0.227** |
| | | (-1.93) | | (-27.19) | | (-2.15) |
| FinII× lnFinSI | | -0.013*** | | 0.258*** | | -0.687*** |
| | | (-3.80) | | (41.18) | | (-12.04) |
| PoS | -0.665*** | -0.815*** | -0.033** | -0.684*** | -0.691*** | -0.014*** |
| | (-25.92) | (-2.90) | (-2.43) | (-7.90) | (-11.97) | (-2.84) |
| ATech | 0.628*** | 0.023*** | 0.003** | 0. 843*** | 0.012*** | 0.003** |
| | (42.98) | (6.94) | (2.93) | (13.13) | (4.01) | (36.88) |
| lnTop | 0.109** | 0.118*** | 0.702*** | 0. 042 | 0.212** | 0.035*** |
| | (2.84) | (10.94) | (3.31) | (0.440) | (2.00) | (10.88) |
| Net Effect | 0.012 | -0.055 | -0.506 | 0527 | -0.660 | -2.311 |
| Year Fixed Effect | Yes | Yes | Yes | Yes | Yes | Yes |
| Country Fixed Effect | Yes | Yes | Yes | Yes | Yes | Yes |
| AR(1) | (0.4569) | (0.243) | (0.3532) | (0.228) | | |
| AR(2) | (0.0718) | (0.892) | (0.2527) | (0.412) | | |
| Sargan Test | (0.2672) | (0.075) | (0.5427) | (0.668) | | |
| Hansen Test | (0.1723) | (0.626) | (0.3892) | (0.735) | | |
| Wald $\chi^2$ | 14492.76*** | 1387.68*** | 374.19*** | 457.82*** | 200.46*** | 238.04*** |
| Instruments | 21 | 21 | 24 | 24 | | |
| Country | 47 | 47 | 47 | 47 | 47 | 47 |
| Observations | 793 | 793 | 752 | 752 | 839 | 839 |

*Note(s): ***,**,* signify 1%, 5% , 10% significance levels respectively. FinII: Financial Inclusion Index, lnFinAI: Natural logarithm of FinTech Adoption Index, lnCChI: Natural logarithm of Climate change Index, lnFinSI: Natural logarithm of Financial Stability Index, lnTop: Natural logarithm of Trade openness, ATech: Access to Technology, PoS: Political Stability. Mean of lnFinAI is 3.235 and lnFinSI is 3.311.*

#### *4.7.2.1 Relationship between financial inclusion and climate change*

The findings also revealed that higher levels of financial inclusion and FinTech adoption are associated with lower climate change index values, according to the findings. The financial inclusion index and the FinTech adoption index both demonstrate negative coefficients (β=-0.027, p<0.01) and -0.245, p<0.01, respectively. These results indicate that these factors may have the potential to alleviate the impact of climate change. The existence of this unforeseen inverse correlation presents a challenge to established beliefs and emphasises the urgency for additional investigation into how the adoption of financial technology (FinTech) and financial inclusion may positively impact the environment.

*4.7.2.2 Moderating roles of FinTech adoption and financial stability on financial inclusion and climate change*

Additionally, it is worth noting that the coefficient of moderation between FinTech adoption and financial inclusion is negative and statistically significant ($\beta = -0.012$, $p<0.01$). This suggests that the adoption of FinTech and financial inclusion work in tandem to alleviate the effects of climate change, indicating the existence of a mutually reinforcing association between these two factors that promotes environmental resilience (Ozili, 2023).

*4.7.2.3 Moderating roles of financial stability on financial inclusion and climate change*

In a similar vein, the coefficient of interaction between the financial inclusion index and the financial stability index is both negative and statistically significant ($\beta = -0.012$, $p<0.01$). This finding underscores the potential for financial inclusion and stability to work together in a concerted effort to tackle the challenges posed by climate change.

Significantly, the coefficients of ($\beta = -0.055$ and ($\beta = 0.012$) for the net effect of the baseline model indicate a complex relationship between the variables under consideration. This ambiguity highlights the need for comprehensive and nuanced policy interventions by emphasising the complexity of the interactions between financial factors and climate change outcomes. Furthermore, it is noteworthy that political stability and technological accessibility emerge as substantial predictors of climate change index values, exhibiting anticipated positive and negative coefficients, respectively. The aforementioned results highlight the significance of incorporating socio-political and technological elements into strategies aimed at mitigating climate change, thereby emphasising the multidimensionality of the factors that influence its dynamics.

*4.7.2.4 Sensitivity analysis and robustness testing*

The analysis emphasizes the importance of conducting robustness testing and sensitivity analysis in the context of FinTech adoption, financial stability, and climate change. By utilizing additional estimation techniques such as the random effects model and the two-step difference GMM, the study aims to enhance the

reliability and robustness of its findings. The results obtained from these techniques align closely with those from the baseline model, indicating consistency and dependability across different methodologies. Specifically, the two-step difference GMM technique proves effective in addressing endogeneity and dynamic panel data concerns, validating the correlations between financial variables and climate change outcomes. The random effects model, by incorporating unobserved variations among individual units, further strengthens the reliability of the results. The consistency of outcomes across various estimation techniques underscores the interconnectedness of climate change, financial inclusion, FinTech adoption, and financial stability.

Through sensitivity analysis and robustness testing, the research not only enhances the credibility of its conclusions but also broadens the applicability of the findings to diverse contexts. The study's implications extend to academics, policymakers, and stakeholders, offering valuable insights for informing policy decisions, designing interventions, and guiding future research efforts aimed at addressing the challenges posed by climate change.

#### *4.7.2.5 Further sensitivity analysis and robustness testing using quantile regression*

Performing further sensitivity analysis and robustness testing by quantile regression might provide valuable insights into the relationships among climate change, financial inclusion, FinTech adoption, and financial stability across different distribution segments. The coefficients vary across different quantiles, as seen in Table 4.9. This enhances understanding of the connections between these variables at different points in the distribution of the climate change index. The model's robustness is shown by the persistent relevance of the constant component across all quantiles. The size of the constant swings somewhat across quantiles, indicating potential differences in the starting values of the climate change index throughout different parts of the distribution.

Table 4.7 Quantile Regression Results on Financial Inclusion, FinTech Adoption, Financial Stability and Climate Change

| | **Dependent variable: lnCCh** | | | | |
|---|---|---|---|---|---|
| Variable | **Q.10** | **Q.25** | **Q.50** | **Q.75** | **Q.90** |
| Constant | 5.334*** | 5.225*** | 5.609*** | 2.341*** | 3.751*** |

| | | | | | |
|---|---|---|---|---|---|
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| FinII | 0.102** | 0.198*** | -0.042** | 0.327*** | 0.103*** |
| | (0.002) | (0.000) | (0.005) | (0.000) | (0.000) |
| lnFinAI | 0.452* | -0.303** | -0.366*** | -0.379*** | -0.627*** |
| | (0.008) | (0.002) | (0.000) | (0.000) | (0.001) |
| FinII× lnFinAI | 0.798*** | 0.976*** | 0.832*** | 0.691*** | 0.587*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| lnFinSI | -0.344*** | -0.318*** | -0.269*** | -0.220*** | -0.215* |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.036) |
| FinII× lnFinSI | -0.843*** | 0.013 | 0.116* | 0.192** | 0.098*** |
| | (0.000) | (0.892) | (0.014) | (0.002) | (0.000) |
| PoS | -0.071* | 0.198*** | 0.006 | 0.616*** | 0.161*** |
| | (0.041) | (0.000) | (0.610) | (0.000) | (0.000) |
| ATech | 0.151*** | 0.244*** | -0.007 | -0.010 | -0.087* |
| | (0.000) | (0.000) | (0.602) | (0.500) | (0.008) |
| lnTop | -0.014 | -0.072** | -0.008 | 0.147*** | -0.100*** |
| | (0.768) | (0.005) | (0.574) | (0.000) | (0.000) |
| Gini Index | -0.623*** | -0.216*** | 0.003 | -0.076*** | 0.049* |
| | (0.000) | (0.000) | (0.757) | (0.000) | (0.016) |
| Pseudo $R^2$ | 0.854 | 0.922 | 0.901 | 0.880 | 0.851 |
| Observation | 839 | 839 | 839 | 839 | 839 |

*Note(s): ***,**,* signify 1%, 5% , 10% significance levels respectively. p-values are in parenthesis. lnFinAI: Natural logarithm of FinTech Adoption Index, lnCChI: Natural logarithm of Climate change Index, lnFinSI: Natural logarithm of Financial Stability Index, lnTop: Natural logarithm of Trade openness, ATech: Access to Technology, PoS: Political Stability, Gini Index: Income Distribution.*

Furthermore, there are differences in the patterns shown in the coefficients for financial inclusion and FinTech adoption across quantiles. The financial inclusion index coefficient is positive and statistically significant at the 10% level for the tenth quantile. However, at quantiles Q.25, Q.50, Q.75, and Q.90, the coefficient turns negative and statistically significant at the 1% level. The association between climate change and financial inclusion may vary depending on one's place in the distribution. Segments with higher climate change index values may experience a more significant influence of financial inclusion in reducing climate change (Cianconi et al., 2020).

The coefficient representing FinTech adoption shows consistent fluctuation across quantiles. The coefficient for the tenth quantile is positively and statistically significantly significant at the 10% level. As the quantile rises to Q.25, Q.50, Q.75, and Q.90, it turns negative and shows statistical significance at the 1% level. Regions with higher index values may suffer a decrease in climate change index

values as a result of increasing FinTech adoption, indicating that the impact of FinTech adoption on climate change may vary throughout different parts of the distribution (Sadiq et al., 2024).

Furthermore, there is variance in the coefficients of the interaction terms between financial components financial inclusion index and FinTech adoption index, financial inclusion and financial stability between quantiles. The interaction terms have consistently negative coefficients and are statistically significant across all quantiles (Li & Samimi, 2022). The coefficients vary in size, indicating that the collective effects of financial inclusion, FinTech adoption, and financial stability on climate change may vary in importance across different sectors of the distribution. Quantile regression outputs improve our understanding of the relationships between financial factors and climate change impacts in more depth. This highlights the need to consider the heterogeneity among various parts of the distribution. Quantile regression enhances the dependability and accuracy of our findings by considering fluctuations in the coefficients across quantiles. Policymakers and stakeholders may benefit from the insights presented to build targeted policies to successfully address the issues of climate change.

### *7.2.6 Discussion on the relationship between FinTech adoption, financial stability, financial inclusion and climate change*

The discussion covers the direct relationship between financial inclusion and climate change and the moderating influence of FinTech adoption and financial stability on the relationship between financial inclusion and climate change in SSA countries. The dynamics between FinTech adoption and its influence on financial stability and inclusion are critically intertwined with climate change adaptation strategies within SSA. Descriptive statistics provide a quantitative foundation for understanding the breadth and depth of these relationships. Notably, FinTech's role in enhancing financial inclusion by making financial services accessible even in remote areas affected by climate challenges becomes evident through these statistics. FinTech platforms, through the provision of innovative financial products such as mobile money, digital wallets, and blockchain-based solutions, have shown a positive relationship with increased financial inclusion (Mhlanga, 2022a). This relationship is crucial in regions where climate change poses significant risks to

economic stability. For instance, mobile money services allow individuals in areas lacking physical banking infrastructure to access financial services, which is vital for managing the economic impacts of climate variability.

The statistical analysis further reveals that FinTech adoption contributes to financial stability by enabling more resilient economic practices (Landi, 2023). For example, through FinTech, small-scale farmers in vulnerable regions can access weather-indexed insurance and microloans, which are essential for mitigating the risks associated with climate-induced natural disasters. Moreover, the descriptive statistics highlight that with greater financial inclusion facilitated by FinTech, communities are better equipped to invest in climate-resilient infrastructure and sustainable practices. This investment is not only a step towards mitigating the effects of climate change but also a significant move towards achieving long-term financial stability in these regions.

Furthermore, the insights provided by the regression analysis in this study regarding the relationships between climate change, financial inclusion, FinTech adoption, and financial stability are invaluable. The findings reveal noteworthy trends that carry significant ramifications for policy formulation and implementation in addressing climate-change issues. The positive coefficient of the lagged climate change index signifies the enduring nature of climate change trends over time, which is consistent with prior investigations on the stagnation of climate change repercussions (Alare et al., 2022). This underscores the necessity to employ strategies aimed at mitigating and adapting to the consequences of climate change. Contrary to conventional wisdom, the correlation between climate change index values, financial inclusion, and FinTech adoption is negative (Alam et al., 2023; Li & Samimi, 2022; Warren-Myers & Cradduck, 2023). This finding underscores the criticality of financial innovation in addressing concerns related to environmental sustainability.

Historically, there has been no direct correlation between financial inclusion, technological advancements in finance, and efforts to mitigate climate change. According to our findings, these attributes could be of critical importance in reducing the adverse impacts of climate change (He et al., 2022). Financial inclusion, commonly understood as the enhancement of access to financial services

and resources, is a widely recognised approach to mitigating poverty and fostering economic expansion is countries such as Ghana, Nigeria and Keya (Baptista et al., 2022b). However, its potential to mitigate climate change has only recently emerged. According to our research, a negative coefficient of financial inclusion indicates that greater financial inclusion is associated with lower climate change index values. By improving the availability of financial services, such as credit, insurance, and savings accounts, communities and individuals may be more inclined to adopt climate-resilient technologies and practices (Baptista et al., 2022b).

The adoption of Fintech, which encompasses several technological advancements in the financial sector, has emerged as a major factor in modern finance. The predominant emphasis of FinTech has been on enhancing the efficacy, accessibility, and inclusivity of financial services, whereas its implications for environmental sustainability have received limited consideration. The negative coefficient indicates that increased Fintech usage is associated with decreased climate change index values, according to our analysis. Blockchain applications, mobile payment systems, and digital wallets are examples of FinTech innovations that may facilitate environmentally responsible financial transactions and investments.

The findings of our research align with the conclusions drawn by Bouraima et al. (2024), suggesting that environmental resilience can potentially be strengthened through the convergence of financial inclusion and technological advancements in finance. The adoption of financial technology and financial inclusion may enable businesses and individuals to access technical tools and financial services, thus enabling them to make informed investments and decisions that contribute to climate change adaptation and mitigation (Nuruzzaman et al., 2024). The complex and interdependent relationship between financial inclusion and financial stability as well as financial inclusion and FinTech adoption underscores the remarkable interaction effects among financial components in addressing climate change issues. Consistent with the findings of Brunetti et al. (2021), the results highlight the potential for synergistic effects when examining the interplay between financial

inclusion, FinTech adoption, and financial stability concerning environmental resilience.

Financial stability, FinTech adoption, and financial inclusion are all critical components of the financial ecosystem, and their significance extends to climate change mitigation and adaptation (Azam et al., 2023). Each of these variables has the potential to contribute substantially to environmental sustainability. According to the findings of our study, the confluence of these variables could potentially have a significant impact on addressing climate change issues. The convergence of financial inclusion and FinTech adoption increases the likelihood that organisations and individuals with access to financial services and technological advancements will adopt climate-resilient practices and technologies (George & Merrill, 2021). FinTech innovations such as digital payment systems and mobile banking applications may enable marginalised communities in countries like Ethiopia and Senegal to access financial services, enabling them to participate in climate-friendly initiatives such as sustainable agriculture or renewable energy projects.

Stable and inclusive financial systems are more effectively equipped to support endeavours aimed at adapting to and mitigating climate change. Inclusive financial services enable a wide range of stakeholders to participate in climate-resilient infrastructure and technology, whereas a secure financial system facilitates long-term investment in such initiatives. The quantile regression results illustrate the variations in the relationships between financial variables and the impacts of climate change on different segments of the distribution. Variations in the coefficients across quantiles suggest that the effects of FinTech adoption and financial inclusion may vary according to the degree of vulnerability to climate change, even though overall trends remain constant (Ljumovic et al., 2023)

The study provides further evidence in line with the findings of Liu et al. (2024), which emphasise the potential of FinTech implementation to enhance climate resilience through advancements in sustainable investment, risk management, and insurance. The results provide empirical evidence in favour of the notion that advancements in financial technology could revolutionise traditional financial procedures, enabling more streamlined and efficacious approaches to address climate change issues. The research demonstrates a correlation between

increased Fintech usage and declining climate change index values, suggesting that Fintech solutions may assist in mitigating the impacts of climate change. This aligns with the findings of Galeotti et al. (2023), who highlight the significance of financial technology in improving risk management methodologies, introducing innovative insurance products tailored to climate-related risks, and advancing sustainable investment strategies.

This analysis underscores the importance of surmounting regulatory and infrastructural barriers to ensure the equitable availability of FinTech solutions. This aligns with concerns raised in previous studies, such as that of Udeagha and Ngepah (2023), which emphasise the necessity for collective efforts to tackle regulatory obstacles and reduce the disparity in digital accessibility. Our research underscores the criticality of establishing infrastructure development initiatives and inclusive FinTech policies to ensure that the benefits of FinTech adoption are accessible to all segments of society, particularly those most vulnerable to the impacts of climate change.

Financial inclusion may potentially enable businesses and individuals to allocate resources towards the development of climate-resilient technologies or sustainable practices. In a similar fashion, the adoption of FinTech may spur environmentally conscious consumption patterns or advance the financing of green initiatives. This views financial inclusion as a mechanism for advancing more extensive social and environmental objectives, which is consistent with the evolving understanding of Financial Inclusion Theory (Beegle & Christiaensen, 2019). Further emphasising the possibility of a synergistic effect are the adverse moderating effects of financial stability and FinTech adoption on the relationship between climate change and financial inclusion. According to Ozili et al. (2023), this discovery implies that these elements may mutually support one another in their efforts to enhance environmental resilience. The positive impact of political stability is consistent with the principles of Modernization Theory, which postulate that a stable political climate can enable the effective allocation of resources and long-term planning to tackle environmental challenges. On the contrary, the adverse impact of technology accessibility indicates a necessity for additional investigation

concerning the ecological impact of particular technologies and possible inadvertent repercussions (Hwang et al., 2021).

While acknowledging the significant contributions of this study, it is also critical to understand its limitations. We were unable to establish causal correlations between the variables due to the cross-sectional design of the study data. The study emphasises specific financial factors while disregarding other potentially influential elements that could affect the outcomes of climate change. Further research could address these limitations by incorporating longitudinal data and a broader range of variables, thereby yielding a more comprehensive understanding of the interrelationships between financial factors and climate change. This study ultimately provides significant insights into the potential of financial stability, FinTech adoption, and financial inclusion to mitigate the impacts of climate change. Nevertheless, further investigation is necessary to ascertain the precise mechanisms through which these variables impact one another, and to develop efficacious policy interventions that promote environmental sustainability.

### 4.7.3 Association between economic growth, climate change and financial stability

The results of the two-step system GMM are presented in Table 4.10 on the moderating effect of economic growth on the relationship between climate change and the financial stability of SSA countries. The diagnostic statistics were used to examine the validity and reliability of regression models in the study. Autocorrelation measures AR (1) and AR (2) show no significant autocorrelation in the residuals at lag 1 and lag 2, ensuring independence of error terms over time. The Sargan Test with a p-value of 0.7309 confirms the validity of instrumental variables, enhancing the credibility of the instrumental variable approach. The Hansen Test's p-value of 0.5873 indicates the instruments used are valid, free from endogeneity issues, and dependable. The Wald $\chi 2$ statistic shows very significant p-values for all models, suggesting the coefficients are significantly different from zero, validating the statistical significance and adequacy of the regression models. Overall, the diagnostic statistics support the effectiveness, validity, and reliability of the regression models, ensuring the suitability of the data for analysis and interpretation.

The analysis explores the relationship between past financial stability and future financial stability in nations. The statistical data ($\beta$= 1.752, $p<0.01$) indicates a significant positive nexus between the two variables. This suggests that countries with a history of financial stability are more likely to maintain stability in the future. The findings highlight the importance of establishing and maintaining robust financial infrastructures to withstand economic fluctuations and external disruptions. This persistence in financial stability indicates a level of resilience.

Table 4.8 Regression Results on Climate Change, Economic growth, and Financial Stability

| | Dependent Variable: FinSI | | |
|---|---|---|---|
| | Baseline Model | Sensitivity and Robustness Testing Models | |
| Variable | System GMM | Difference GMM | Random Effect |
| | (1) | (2) | (3) |
| | lnCChI | lnCChI | lnCChI |
| Constant | 3.352*** | 4.353*** | 0.622*** |
| | (46.73) | (24.17) | (23.52) |
| FinSI(-1) | 1.752*** | 0.269*** | |
| | (18.17) | (4.33) | |
| lnCChI | 0.103*** | 0.015*** | 0.019*** |
| | (3.97) | (3.42) | (4.60) |
| GDPGR | 8.393*** | 0.726*** | 0.118*** |
| | (191.75) | (13.50) | (27.93) |
| lnCChI × GDPGR | 0.114*** | 0.089*** | 0.023*** |
| | (321.94) | (13.60) | (6.94) |
| PoS | 0.013** | 0.024*** | 0.008*** |
| | (2.94) | (3.56) | (14.54) |
| ATech | 0.003*** | 0.004 | 0.091*** |
| | (7.25) | (5.41) | (7.87) |
| lnTop | -0.101*** | -0.076*** | -0.038** |
| | (-8.71) | (24.17) | (-2.29) |
| Net Effect | 0.248 | 0.128 | 0.048 |
| Year Fixed Effect | Yes | Yes | Yes |
| Country Fixed Effect | Yes | Yes | Yes |
| AR(1) | (0.2662) | (0.5892) | |
| AR(2) | (0.3285) | (0.4099) | |
| Sargan Test | (0.7309) | (0.4572) | |
| Hansen Test | (0.5873) | (0.3193) | |
| Wald $\chi^2$ | 209.92*** | 1157.95*** | 16.82*** |
| Instruments | 24 | 23 | |

| | | | |
|---|---|---|---|
| Country | 47 | 47 | 47 |
| Observations | 793 | 792 | 838 |

*Note(s): ***,**,* signify 1%, 5% , 10% significance levels respectively. lnCChI: Natural logarithm of Climate change Index, lnFinSI: Natural logarithm of Financial Stability Index, GDPGR: Gross Domestic Product Growth Rate: lnTop: Natural logarithm of Trade openness, ATech: Access to Technology, PoS: Political Stability. Mean of GDPGR is 1.275*

#### *4.7.3.1 Association between climate change and financial stability*

The results presented in Table 4.8 revealed that financial stability is significantly and positively linked with the climate change index (β = 0.103, p<0.01). Contrary to conventional wisdom, the discovered correlation between deteriorating financial stability and warming climatic conditions is considerably more complex (K. Ratnawati, 2020). One plausible explanation could be that countries grappling with climate issues have implemented adaptation strategies (Chinoda & Kapingura, 2024). The potential implementation of these proactive measures could enhance financial preparedness and resilience, thereby bolstering existing levels of stability. Conversely, financially stable countries may be better equipped to cope with climate risk, leading to a deceleration in the decline of their climate change index, if there is reverse causation (Ndombi Avouba et al., 2023).

#### *4.7.3.2 Moderating effect of economic growth on the association between climate change and financial stability*

The result also shows that economic growth has a significant and positive effect on financial stability (β = 8.393, p<0.01). The anticipated positive impact of economic growth on financial stability is consistent with conventional economic theory. The result provides substantial support for the notion that stable financial institutions and markets are the result of resilient economic conditions. The complex relationship between economic growth and climate change (β = 0.114, p<0.01) suggests that while economic growth may mitigate certain adverse effects of climate change on financial stability, the relationship itself is complex (Sofi & Zamir, 2019). It is essential to comprehend the intricacies of this interaction to formulate comprehensive strategies that enhance economic resilience in the face of climate-related risks.

The study emphasises the positive relationships between financial stability and technological accessibility (β= 0.003, p<0.01) and political stability (β= 0.013,

$p<0.05$). Political stability fosters confidence and reduces uncertainty, thereby establishing a dependable environment for financial markets and economic operations, which ultimately contributes to increased stability. Enhanced technological accessibility for the financial system fortifies its resilience against internal and external disruptions by promoting efficiency, risk management, and financial inclusion.

There exists a negative relationship ($\beta = -0.101$, $p<0.01$) between financial stability and trade openness. Although trade openness is typically associated with economic development and growth, it may also expose countries to external financial disruptions and economic instability, according to the findings. This unexpected correlation underscores the complex relationship between worldwide trade trends and financial stability, placing additional emphasis on the necessity for additional investigation into the underlying mechanisms that govern this association (Hao et al., 2023). Additionally, it is critical to take into account the possibility of selection bias, as countries with less robust financial systems might engage in restricted global trade, thus establishing a misleading downward correlation. The findings offer valuable perspectives on the myriad elements that impact financial stability, underscoring the imperative for nuanced policy measures to fortify economic robustness in an ever-evolving international context.

*4.7.3.3 Sensitivity analysis and robustness testing*

To ensure that the study model is stable, sensitivity analysis and robustness testing were conducted to explore how economic growth influences the relationship between climate change and financial stability. The study utilized random effect and two-step difference GMM models. The results showed a high level of consistency between the different model approaches, indicating the robustness and reliability of the findings. By systematically assessing changes in model specifications, the study aimed to enhance the validity of its empirical results.

The study findings consistently demonstrated a strong relationship between financial stability, economic development, and climate change across various model frameworks. This consistency in results suggests the dependability and reliability of the study's conclusions when using diverse estimating approaches. The study's rigorous methodology and the agreement between the baseline model and

alternative specifications strengthen the trustworthiness of the results and their implications for theory and practice.

Overall, the study's robustness testing and sensitivity analysis confirmed the reliability of the findings regarding how economic development moderates the association between financial stability and climate change. The consistent application of multiple model methodologies enhances the credibility of the empirical data and contributes to a deeper understanding of the complex interplay between environmental, economic, and financial factors.

*4.7.3.4 Further sensitivity analysis and robustness testing using quantile regression*

The diagnostic test statistics show the effectiveness of quantile regression models in explaining financial stability conditions, especially at lower quantiles where the values are higher. The pseudo-R-squared values indicate that these models have strong explanatory power, capturing the diverse impacts of economic development and climate change on financial stability across various sectors of the distribution. This suggests that quantile regression analysis can offer valuable insights

Table 4.9 Quantile Regression Results on Climate Change, Economic Growth, and Financial Stability

| | **Dependent Variable: Financial Stability** | | | | |
|---|---|---|---|---|---|
| Variable | **Q.10** | **Q.25** | **Q.50** | **Q.75** | **Q.90** |
| Constant | 0.376*** | 0.290*** | 1.413*** | 3.113*** | 5.228*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| lnCChI | 0.472*** | 0.385*** | 0.102** | 0.013 | 0.111*** |
| | (0.000) | (0.000) | (0.005) | (0.931) | (0.000) |
| GDPGR | 0.678*** | 0.447*** | -0.253*** | -1.109*** | -1.089*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| lnCChI × GDPGR | 0.283* | 1.110*** | 1.033*** | 1.491*** | 1.390*** |
| | (0.074) | (0.000) | (0.000) | (0.000) | (0.000) |
| PoS | 1.103*** | 0.953*** | 0.983*** | 0.600*** | 0.205*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| ATech | 0.139** | 0.132* | 0.244*** | 0.381*** | 0.315*** |
| | (0.005) | (0.039) | (0.000) | (0.000) | (0.000) |
| lnTop | -0.069* | -0.773*** | -0.805*** | -0.383*** | -0.122*** |
| | (0.013) | (0.000) | (0.000) | (0.000) | (0.000) |
| Gini Index | -0.024* | 0.004 | 0.024* | 0.009 | 3.340*** |
| | (0.036) | (0.734) | (0.024) | (0.671) | (0.000) |
| Pseudo $R^2$ | 0.711 | 0.703 | 0.524 | 0.436 | 0.479 |
| Observation | 838 | 838 | 838 | 838 | 838 |

*Note(s): ***,**,* signify 1%, 5% , 10% significance levels respectively. p-values are in parenthesis. lnCChI: Natural logarithm of Climate change Index, lnFinSI: Natural logarithm of Financial Stability Index, GDPGR: Gross Domestic Product Growth Rate: lnTop: Natural logarithm of Trade openness, ATech: Access to Technology, PoS: Political Stability, Gini Index: Income Distribution.*

The study used quantile regression to improve understanding of the relationship between climate change, economic development, and financial stability, by doing further sensitivity analysis and robustness testing. Table 4.11 presents data that provide valuable insights into the relationships among these variables at different quantiles of the distribution. The intercept is significantly positive at the 10th percentile (Q.10), indicating that economic and climatic factors do not initially endanger financial stability. The coefficient for the climate change index is notably larger at this quantile compared to other quantiles. Regions most severely impacted by climate change are more vulnerable to its implications on financial stability (Brunetti et al., 2021).

As quantiles upsurge, the negative association between economic growth and financial stability becomes increasingly noticeable. This indicates that as the economy grows, its impact on financial stability decreases. As countries advance, the additional advantage of economic expansion in enhancing financial stability may decrease. The influence of the interaction term between climate change and economic growth varies depending on the quantile (Oswald & Stern, 2019). At lower quantiles, the positive interaction term between severe climate change and financial stability and economic development is not statistically significant, suggesting a weak potential relationship. However, when the quantiles rise, the interaction becomes more significant and shifts to a positive direction. Regions with more economic success may see a reduction in the impact of climate change on financial stability because of economic growth (Raihan et al., 2022).

Moreover, by using the Gini Index (Income Distribution) as a control variable, we may analyse the impact of income disparity on financial stability. The Q.10 and Q.50 quantiles show a negative coefficient, suggesting that higher income inequality may threaten financial stability, particularly in regions already vulnerable to the impacts of climate change and economic downturns.

*4.7.3.5 Discussion on the association between economic growth, climate change and financial stability*

This study delves into the intricate relationship between economic growth, climate change, and financial stability, supported by robust descriptive statistics. Economic growth, as quantified through various metrics in the descriptive statistics, demonstrates a significant impact on financial stability (Ziyadullayevich, 2022). The findings suggests that stronger economies have better mechanisms to mitigate the effects of climate change, contributing to greater financial stability. Descriptive statistics show that regions with higher economic growth rates tend to have more resources to invest in climate-resilient infrastructure and technologies. These investments are crucial for maintaining financial stability amid the increasing frequency and intensity of climate-related disasters (Brunetti et al., 2021). Furthermore, the economic growth enables these regions to implement effective adaptation strategies, which is evident from the statistical correlation between GDP growth rates and improvements in financial stability indices.

Climate change impacts are reflected in the variability of financial stability across different economic contexts. The descriptive statistics reveal that economies with stagnant or negative growth are more vulnerable to the destabilizing effects of climate change. This vulnerability is quantified through higher volatility in financial stability measures in these regions, underscoring the need for targeted economic policies to foster growth and resilience (Brunetti et al., 2021). Financial stability itself is shown to be a critical factor that can either amplify or mitigate the effects of climate change on economic systems. Economies that maintain high levels of financial stability can better withstand and recover from the economic disruptions caused by climate change, as suggested by the lower volatility in their financial indices.

The findings demonstrate a robust relationship, aligning with predictions and confirming prior studies (Ratnawati & Yuana, 2022). This example underscores the significance of strong financial institutions in ensuring stability during economic fluctuations. However, it's important to acknowledge the heterogeneity in economic development across the various SSA countries sampled in this study. This variation in income levels might influence the strength of the positive association between

economic growth and financial stability. For instance, countries with a lower GDP, like Malawi or Niger, might experience a different relationship between economic growth and financial stability compared to more developed SSA countries like South Africa or Botswana (Ndombi Avouba et al., 2023). Developing enduring financial stability is vital for the development and sustainability of the national economy, underscoring its important importance. This study explores the relationship between the climate change index and financial stability, as suggested by Chinoda and Kapingura (2024), revealing a complex link that differs from conventional expectations. The interaction between financial stability and environmental factors is intricate, challenging traditional views and prompting a more sophisticated understanding of their connection. This study suggests potential explanations for this unexpected correlation, drawing on prior studies conducted by Ratnawati and Yuana (2022) and Ndombi Avouba et al. (2023) in SSA countries like Gambia and Ethiopia.

One potential cause is the implementation of adaptation strategies by countries experiencing climate risk. Naser and Pearce (2022) suggest that countries facing challenges from climate change may have proactively enhanced their economic resilience. Investments in infrastructure and policy interventions are two adaptation techniques that might enhance the resilience of financial systems to climate change and future environmental shocks. Another possibility proposed to explain the connection might be the concept of reverse causality. Countries with robust economies are more likely to be able to mitigate the decline of their climate change index due to their resources and established institutions for addressing climate change, as stated by (Nuruzzaman et al., 2024). This highlights the complex feedback loops involved in the relationship between climate change and financial stability, indicating a mutual interaction where financial stability responds to and influences environmental conditions. These hypotheses provide insight into the striking link but also emphasise the need for more study and empirical validation. Robust methodology and interdisciplinary methods are essential for comprehending the complex of the relationship between climate change and financial stability, as acknowledged in the study.

The study demonstrates that economic expansion significantly and positively impacts financial stability, in line with accepted economic theory and earlier research (He et al., 2022; Sofi & Zamir, 2019). This study emphasises the vital role of a thriving economy in establishing stable financial systems, where robust economic conditions support the effective functioning of financial institutions and markets. The study suggests that economic development might mitigate the adverse effects of climate change on financial stability by examining the relationship between economic growth and climate change. A thriving economy might potentially reduce the impact of climate change by fostering options for adaptation and resilience.

Increased income might lead to further investment in climate-resilient infrastructure such as flood barriers, renewable energy systems, and disaster preparedness programmes. Economically stable nations should invest in climate-resilient infrastructure to withstand environmental shocks more effectively (Mhlanga, 2022a). This will assist them in enduring the difficult situation and maintaining their financial stability (Brunetti et al., 2021). Technological innovation, a result of economic growth, might be essential in addressing the impacts of climate change. To mitigate the effects of climate change and enhance societal resilience, sustainable agricultural practices, enhanced climate monitoring systems, and the advancement of cleaner energy sources should be used (Sadiq et al., 2024). Advanced countries may improve their economic stability by increasing their ability to adapt to changing environmental conditions via technical advancements.

Enhancing economic resilience to environmental risks by decreasing dependence on climate-sensitive industries is a key objective of economic diversification, a fundamental aspect of economic growth. Governments may safeguard their financial systems from environmental shocks by promoting a diverse and robust economy (Azam et al., 2023). This involves incorporating a range of industries that are less vulnerable to the adverse impacts of climate change. The government's capacity to tackle climate change via policy interventions is enhanced during periods of economic growth. Prosperous nations may adopt strategies like carbon pricing and renewable energy subsidies to benefit both the

environment and their economy simultaneously. Economic growth may mitigate the effects of climate change on financial stability, and this study illuminates the mechanisms through which this occurs (Yang et al., 2022).

Research conducted by Ndombi Avouba et al. (2023) and Raihan et al. (2022) has shown that technology accessibility and political stability play crucial roles in enhancing the resilience and trust of financial systems. The positive influence identified among these three factors provides more evidence for these conclusions. Enhanced financial system stability stems directly from the beneficial impacts of technology accessibility on financial inclusion, efficiency, and risk management. Political stability enhances the reliability and trustworthiness of financial markets, hence fostering investment and economic activity.

The unexpected negative relationship between trade openness and financial stability indicates the need for more studies to investigate potential factors such as selection bias (Hao et al., 2023). This unexpected finding challenges traditional notions of the beneficial impact of trade openness on financial stability, highlighting the complex nature of global trade dynamics and their nuanced influence on financial institutions. The study discovered that contrary to the popular knowledge that more trade leads to greater development and wealth, trade openness might make nations susceptible to external financial shocks and economic instability, thereby undermining their financial stability. It is crucial to pinpoint the specific ways in which trade openness impacts financial stability and create focused policy measures to mitigate associated risks.

Endogenous Growth Theory suggests that nations facing climate-related issues may invest in adaptation strategies to improve their financial resilience and stability (Chinoda & Kapingura, 2024). Conversely, economically strong countries may be better able to handle climate-related dangers, slowing their climate change index drop (Ndombi Avouba et al., 2023). Economic theory states that healthy economies lead to stable financial institutions and markets, supporting the idea that economic expansion improves financial stability. The complex relationship between economic growth and climate change necessitates further research into how economic growth can mitigate climate change and boost financial resilience (Sofi & Zamir, 2019). Financial stability also depends on technical accessibility and

political stability, according to the report. Modernization Theory states that a stable political atmosphere boosts confidence and reduces uncertainty, stabilising financial markets. Technological advancement may improve financial inclusion, risk mitigation, and efficiency, strengthening the financial system. The negative association between trade openness and financial stability is unknown and warrants more study. Selection bias and country-specific trade trends may affect this conclusion (Hao et al., 2023).

Further expanding the debate, further robustness tests and sensitivity studies utilising quantile regression provide insight into how climate change, GDP growth, and financial stability interact at different points in the distribution. Studying the influence of climate change and economic development on financial stability involves considering heterogeneity. Research indicates that these linkages are intricate and have varied effects throughout various segments of the distribution (Batten et al., 2021). The study employs quantile regression to examine the association between climate change, GDP growth, and financial stability at various points in the distribution, alongside the baseline study, by examining the findings of further sensitivity analysis and robustness tests. This technique offers a nuanced perspective, highlighting the diverse effects across different segments of the distribution and emphasising the significance of accounting for heterogeneity when examining the influence of climate change and economic growth on financial stability (Batten et al., 2021).

Quantile regression research provides interesting insights into the distributional relationships between climatic change, economic progress, and financial stability. The constant term has a significant positive effect at the lowest quantile, indicating a foundational level of financial stability despite adverse economic and environmental conditions. Raihan et al. (2022) suggest that some regions may maintain financial stability while facing significant challenges. Climate change index varies between quantiles, with lower quantiles having significantly greater values compared to higher quantiles. Some populations are more vulnerable to climate-related disruptions, and financial stability is more affected by climate change in severely impacted regions (Nkwi et al., 2023). As quantiles increase, the influence of economic growth on financial stability

decreases, indicating diminishing advantages of GDP growth for financial stability. The complex outcome emphasises the intricate correlation between GDP growth and financial stability, suggesting that as countries progress economically, GDP growth may become less helpful in enhancing financial stability (Hurlimann et al., 2021).

Various quantiles demonstrate varying effects of the interaction term between the climate change index and economic growth. Higher quantiles demonstrate a progressively more substantial and positive relationship, whereas lower quantiles reveal a positive relationship that is not statistically significant. Raihan et al. (2022) discovered that regions experiencing more economic development are more resilient to the adverse effects of climate change on their financial security. Economic growth may help mitigate the consequences of climate change. The quantile regression analysis findings indicate that the relationships between climatic change, economic development, and financial stability are intricate and have several aspects. Considering heterogeneity is crucial while analysing these processes.

The study assesses potential biases, threats to internal validity, and other limitations inherent in the research process. Factors that may influence the reliability and applicability of findings include measurement errors, omitted variable bias, and sample bias (Hao et al., 2023). Besides, selection bias may lead to a more noticeable unfavourable association between countries with weaker financial systems and their participation in international trade. This understanding emphasises the need to thoroughly examine confounding variables and carry out robust empirical research when assessing the relationship between trade openness and financial stability.

### 4.7.4 Relationship between financial stability, FinTech and climate change

The diagnostic data presented in Table 4.12 compares the baseline regression model with sensitivity and robustness testing models. The analysis focuses on autocorrelation, instrument validity, and the significance of regressors. The AR (1) and AR (2) statistics suggest that the sensitivity and robustness testing models have lower autocorrelation in residuals compared to the baseline model. Both Sargan and Hansen tests show p-values above 0.05, indicating the validity of instruments used

in all models. The Wald $\chi 2$ test reveals that the combined impact of regressors on the dependent variable is statistically significant at the 1% level in all models.

Table 4.10 Regression Results on FinTech Adoption, Financial Stability and Climate Change

| | Dependent Variable: lnCChI | | |
|---|---|---|---|
| | Baseline Model | Sensitivity and Robustness Testing Models | |
| Variable | System GMM | Difference GMM | Random Effect |
| | (1) | (2) | (3) |
| | lnFinAI | lnFinAI | lnFinAI |
| Constant | 7.128** | 7.037*** | 6.531*** |
| | (3.01) | (10.57) | (7.82) |
| lnCChI (-1) | -0.040*** | -0.039** | |
| | (-7.38) | (-2.33) | |
| lnFinAI | 1.149** | 0.548*** | 0.238** |
| | (1.97) | (15.27) | (2.34) |
| lnFinSI | -0.213*** | -0.466** | -0.203** |
| | (3.94) | (-2.29) | (-2.06) |
| lnFinAI × lnFinSI | -0.091*** | -0.085*** | -0.075** |
| | (-3.39) | (-9.21) | (-2.63) |
| PoS | -0.633*** | -0.549*** | -0.690*** |
| | (-43.09) | (-15.27) | (-11.92) |
| ATech | -0.078** | -0.551*** | -0.011*** |
| | (-2.73) | (-13.80) | (-4.04) |
| lnTop | -0.084** | -0.002 | -0.211** |
| | (2.66) | (0.02) | (1.99) |
| Net Effect | 1.450 | 0.829 | 0.486 |
| Year Fixed Effect | Yes | Yes | Yes |
| Country Fixed Effect | Yes | Yes | Yes |
| AR(1) | (0.7834) | (0.3893) | |
| AR(2) | (0.5321) | (0.1701) | |
| Sargan Test | (0.3366) | (0.2873) | |
| Hansen Test | (0.1725) | (0.1982) | |
| Wald $\chi^2$ | 3505.95*** | 375.71*** | 204.08*** |
| Instruments | 22 | 23 | |
| Country | 47 | 47 | 47 |
| Observations | 793 | 752 | 839 |

*Note(s): ***,**,* signify 1%, 5% , 10% significance levels respectively. lnFinAI: Natural logarithm of FinTech Adoption Index, lnCChI: Natural logarithm of Climate change Index, lnFinSI: Natural logarithm of Financial Stability Index, lnTop: Natural logarithm of Trade openness, ATech: Access to Technology, PoS: Political Stability. Mean of lnFinSI is 3.311.*

#### *4.7.4.1 Relationship between Financial stability and climate change*

The results revealed a significant and negative influence of the lagged climate change index on the climate change index ($\beta$= -7.128, p<0.01). This suggests an

uncommon relationship where lower historical levels of climate change mitigate the current tendencies of climate change. This surprising finding warrants more research on the time-dependent aspects of climate change processes and indicates the potential presence of self-regulating mechanisms within the climate system, where previous impacts may mitigate or counteract present alterations (Sadiq et al., 2024).

#### *4.7.4.2 Moderating influence of financial stability on the link between FinTech adoption and climate change*

An unexpected relationship exists between FinTech adoption, financial stability, and efforts to combat climate change, as shown by the adverse effects of the FinTech adoption index ($\beta$= -1.149, $p<0.01$) and the financial stability index ($\beta$= -0.213, $p<0.01$) on the climate change index. While it is logical to anticipate that stable economies and cutting-edge technology may mitigate the impacts of climate change, the magnitude of their adverse consequences suggests they could have an even more significant influence (Ouyang et al., 2022). The potential mechanisms that influence these relationships, such as how advanced financial tools can support investment in sustainable technologies and practices. This finding emphasises the significance of utilising technological and financial resources to address climate change.

The relationship between FinTech adoption and financial stability in the context of climate change is made more complex by a significant negative interaction ($\beta$= -0.091, $p<0.01$) between the FinTech adoption index and the financial stability index. Individually, these actions contribute to mitigating climate change, but their combined effect seems to be negligible (Alam et al., 2023). To create successful policies, one must comprehend the complex relationship between technological and financial resources in addressing climate change. This interaction can be influenced by factors such as regulatory obstacles and market forces, which may hinder the combined advantages.

The negative relationship between political stability and access to technology with the climate change index, ($\beta$= -0.633, $p<0.05$) and ($\beta$= -0.078, $p<0.05$), supports the widespread belief that technical progress and stable political conditions may alleviate climate change. The unexpected beneficial effect of trade openness

(β=-0.084, p<0.05) raises intriguing questions about balancing economic growth and environmental conservation. Striking a balance between economic interests and environmental considerations is challenging; enhancing trade openness might boost economic development but can inadvertently exacerbate climate change via heightened production and emissions.

The findings of a study also show a net reduction in the adverse effects of climate change (β=1.450) due to the combined influence of various factors. The presence of unexpected patterns and ambiguous relationships in the data suggests that there are underlying mechanisms that are not yet fully understood. This underscores the importance of further research to unravel these complexities and inform more effective climate change mitigation strategies. By gaining a deeper understanding of these interactions, policymakers can develop more targeted interventions to address them.

*4.7.4.3 Sensitivity analysis and robustness testing*

Both the sensitivity analysis and the robustness testing findings are congruent, supporting the stability of the baseline model. Researchers verify the accuracy and plausibility of their results by testing the model using various estimating techniques and parameter adjustments. The baseline two-step system GMM model shows resilience in many scenarios when examining how financial stability moderates the relationship between FinTech adoption and climate change in SSA countries. Results are more reliable when the baseline model, the two-step dynamic GMM, and the random effect models align with each other. The research results are more reliable since the observed connections are consistent. We have shown the stability of the baseline model through sensitivity analysis and robustness testing. The moderating effect of financial stability on the relationship between FinTech adoption and climate change is reliable and not influenced by particular modelling choices.

*4.7.4.4 Further sensitivity analysis and robustness testing using quantile regression*

Table 4.11 Quantile Regression Results on FinTech Adoption, Financial Stability and Climate Change

| | **Dependent Variable:** lnFinSI | | | | |
|---|---|---|---|---|---|
| Variable | **Q.10** | **Q.25** | **Q.50** | **Q.75** | **Q.90** |
| Constant | 1.251*** | 0.290*** | 0.333** | 3.113*** | 2.737*** |
| | (0.000) | (0.000) | (0.009) | (0.000) | (0.000) |
| lnFinAI | 0.498*** | 0.385*** | 0.102*** | 0.013 | 0.205 |
| | (0.000) | (0.000) | (0.005) | (0.931) | (0.000) |
| lnFinSI | 0.717*** | 0.447*** | -0.253*** | -1.109*** | -1.252*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| lnFinAI × lnFinSI | -0.367* | 1.110*** | 1.033*** | 1.491*** | 1.753*** |
| | (0.017) | (0.000) | (0.000) | (0.000) | (0.000) |
| PoS | 1.100*** | 0.953*** | 0.983*** | 0.522*** | 0.412*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| ATech | -0.143* | 0.132* | 0.244*** | 0.381*** | 0.064*** |
| | (0.008) | (0.039) | (0.000) | (0.000) | (0.000) |
| lnTop | 0.750*** | -0.980*** | -1.011*** | -0.648*** | -0.566*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Gini Index | 0.110*** | 0.034 | 0.036 | 0.015 | 0.002 |
| | (0.000) | (0.132) | (0.103) | (0.458) | (0.847) |
| Pseudo $R^2$ | 0.709 | 0.668 | 0.560 | 0.437 | 0.429 |
| Observation | 839 | 839 | 839 | 839 | 839 |

*Note(s): ***,**,* signify 1%, 5% , 10% significance levels respectively. p-values are in parenthesis. lnFinAI: Natural logarithm of FinTech Adoption Index, lnCChI: Natural logarithm of Climate change Index, lnFinSI: Natural logarithm of Financial Stability Index, lnTop: Natural logarithm of Trade openness, ATech: Access to Technology, PoS: Political Stability, Gini Index: Income Distribution.*

Quantile regression analysis was conducted to explore the relationship between FinTech adoption, financial stability, and climate change. The results revealed varying impacts at different quantiles of the FinTech adoption index. At lower quantiles (Q.10 and Q.25), there was a consistent positive correlation between FinTech adoption and climate change, indicating that increased FinTech adoption could potentially worsen climate change concerns at these levels (Galappaththi et al., 2019). However, as the quantiles increased (Q.50, Q.75, and Q.90), the influence of FinTech adoption on climate change diminished. The financial stability index exhibits a consistent negative correlation with climate change across all levels, indicating that a higher degree of financial stability is associated with reduced levels of concern regarding climate change throughout the entire distribution (Brunetti et al., 2021).

The relationship between the adoption of FinTech and financial stability exhibits varying degrees of ramifications, turning negative at lower levels and positive at higher levels. Depending on distributional characteristics, the influence of financial stability on the relationship between FinTech adoption and climate

change might vary. Consistently, control variables such as trade openness, political stability, and access to technology exhibit significant effects on climate change across all levels, underscoring their pivotal role in shaping the outcomes of climate change (Sadiq et al., 2024). As a control variable, the Gini Index provides insight into the relationship between income distribution and climate change, with its applicability differing across quantiles.

The results of the quantile regression analysis offer valuable insights regarding the model's stability and heterogeneity in the context of investigating the relationship between climate change, financial stability, and FinTech adoption (Warren-Myers & Cradduck, 2023). Consistent patterns observed at different quantiles of the distribution demonstrate the model's stability, particularly concerning the significant effects of financial stability and particular control variables on climate change outcomes. The consistent findings suggest that factors such as enhanced financial and political stability play a crucial role in mitigating the risks associated with climate change across various regions of the distribution.

The findings of the study indicate that the effects of FinTech implementation and the correlation between FinTech implementation and financial stability differ across quantiles. The presence of diversity underscores the intricate character of these relationships, implying that the impact of FinTech adoption on climate change could vary depending on the level of financial stability and distributional characteristics. The diverse effects of control variables such as trade openness and technological access underscore the importance of considering a range of socio-economic factors when attempting to influence climate change outcomes.

#### *4.7.4.5 Discussion on the relationship between financial stability, FinTech and climate change*

The relationship between financial stability, FinTech adoption, and climate change is a dynamic area of interest that has significant implications for sustainable development in SSA. The analysis of descriptive statistics highlights the pivotal role of FinTech in enhancing financial stability, which in turn influences climate change resilience strategies. Financial stability, as indicated by the variability and robustness of financial indices across SSA, is crucial for supporting FinTech innovations that contribute to climate change mitigation and adaptation. Stable

financial environments encourage the adoption of FinTech solutions that can offer efficient and inclusive financial services, critical in regions prone to the adverse impacts of climate change. These services include mobile banking, microinsurance products tailored to climate risks, and investment in green technologies.

Furthermore, the use of FinTech in these regions promotes financial inclusion, which is essential for enabling vulnerable populations to access financial resources necessary for coping with and adapting to climate variability. The descriptive statistics suggest that higher levels of financial inclusion, facilitated by FinTech, correlate with improved resilience to climate-induced economic disruptions. Literature supports these observations by indicating that financial stability allows for sustained investment in FinTech, which not only addresses immediate financial service needs but also supports long-term climate resilience strategies. Studies such as those by Musah-Surugu et al. (2019) and Sadiq et al. (2024) highlight the critical role of innovative financial technologies in bridging the gap between economic stability and environmental sustainability.

Contrary to conventional wisdom, the significant and negative influence of the previous climate change index on the present climate change index suggests a multifaceted correlation in which levels of climate change in the past may have mitigated current patterns. Consistent with previous research (Sadiq et al., 2024), this unexpected finding indicates the existence of self-regulating mechanisms in the climate system and calls for additional investigation into the timetable of climate change processes.

The unexpected correlations identified between the adoption of Financial Technology (FinTech), financial stability, and climate change underscore the complex interrelationships among these variables and the imperative for a deeper understanding (Musah-Surugu et al., 2019). Contrary to initial expectations, both the FinTech adoption index and the financial stability index exhibit adverse effects on the climate change index. This suggests that the extent of their impact on the outcomes of climate change may be greater than previously acknowledged, thereby challenging established viewpoints (Ouyang et al., 2022). An examination of the effects of financial technology initiatives and measures to ensure financial stability on climate change could furnish crucial insights for stakeholders and policymakers

seeking to address ecological challenges while bolstering economic growth and resilience. For instance, the impact of FinTech adoption on climate change in a country like Ethiopia with a developing financial sector might differ from a more developed SSA nation like South Africa. Similarly, the influence of financial stability on climate change might be stronger in countries with greater political stability, such as Botswana, compared to those facing political instability, like the Democratic Republic of the Congo.

An increasing number of researchers are recognising the complex nature of the relationship between FinTech adoption and financial stability, which demonstrates a significant inverse correlation. This underscores the potential limitations that may hamper the synergistic benefits of financial and technological investments in addressing the issue of climate change (Banna & Alam, 2021b; Panopoulos et al., 2023). This underscores the necessity for a more comprehensive comprehension of the interplay between these elements, encompassing various conditions and constraints that could potentially affect their effectiveness. (Alam et al., 2023). Regulatory barriers and market forces exert a substantial impact on the outcomes of FinTech initiatives aimed at mitigating climate change. Khan et al. (2020) state that the degree to which regulatory frameworks for financial technology can adapt and align with sustainability objectives can either facilitate or impede its incorporation into climate resilience plans.

Berg et al. (2018) noted that the allocation of financial resources towards climate-friendly technology and initiatives could be influenced by market conditions, such as investor inclinations and risk assessments. To fully fathom these complexities, it is imperative to adopt a multidisciplinary approach that incorporates insights from finance, technology, and environmental studies (Warren-Myers & Cradduck, 2023). By grasping these complexities, policymakers and stakeholders can develop more targeted interventions. By capitalising on the correlations between financial stability and FinTech innovation, one can effectively address concerns related to climate change (Plehwe, 2022).

Consistent with prior investigations, the adverse impacts of technology accessibility and political stability on the climate change index provide further support for the notion that stable political circumstances and technological

advancements are indispensable for mitigating the effects of climate change (Sadiq et al., 2024; Suryono et al., 2020). The correlation between trade openness and the climate change index, which is unexpectedly positive, stimulates reflection on the complex dynamics that exist between economic advancement and environmental preservation. Increased trade openness is customarily associated with bolstered concerns regarding climate change; however, the unforeseen correlation suggests that there may be compromises between environmental sustainability and economic prosperity (S. Claessens et al., 2018). The findings underscore the intricate correlation between the dynamics of international trade and the environmental repercussions; they further stress the importance for policymakers to adopt all-encompassing and interconnected policy approaches that strike a balance between environmental and economic considerations.

The net effect signifies a reduction in the adverse consequences of climate change due to the concerted efforts of multiple components. Despite this, the presence of unanticipated patterns and ambiguous connections underscores the necessity for further research to comprehend these complexities. By revealing distinct impacts at different quantiles, the quantile regression analysis emphasises the model's heterogeneity and stability, thereby highlighting the importance of considering distributional characteristics when attempting to comprehend the dynamics of climate change (Galappaththi et al., 2019; Warren-Myers & Cradduck, 2023).

However, the investigation possessed certain limitations. Acknowledging possible biases, internal validity risks, and other methodological limitations is of severe importance. In addition, the findings offer valuable perspectives; however, they warrant meticulous assessment and validation through replication research. The research contributes to the existing body of knowledge by investigating the intricate relationships between climate change, FinTech adoption, and financial stability. This could facilitate the formulation of more targeted and effective policy interventions to address climate change concerns

### 4.7.5 Relationship between financial development, regulatory quality, economic growth and financial stability

The result discusses the regression outcomes related to financial stability, regulatory quality, economic growth, and financial development, emphasizing the importance of diagnostic tests in assessing the models' robustness. The incorporation of interaction terms and control variables enhances the models' explanatory power, as evidenced by significant coefficients and improved model fit statistics. Additionally, the inclusion of year and country-fixed effects strengthens the models by accounting for temporal and cross-country variations. The identification of first-order and second-order autocorrelation underscores the need for serial correlation correction in the regression analysis. The Sargan and Hansen tests confirm the reliability of the instrumental variables used in the estimation process. The Wald $\chi 2$ statistic further supports the models' overall significance, indicating that the explanatory variables collectively have a significant impact on the financial stability index. Overall, the diagnostic tests validate the regression models' ability to capture the complex relationships among financial development, economic growth, regulatory quality, financial stability, and financial growth.

Table 4.12 Regression Results on Economic Growth, Financial Development, Regulatory Quality and Financial Stability

| Variable | Dependent Variable: lnFinSI | | | | | |
|---|---|---|---|---|---|---|
| | Baseline Model | | | Sensitivity and Robustness Testing Models | | |
| | System GMM | | | Difference GMM | | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | GDPGR | GDPGR | GDPGR | GDPGR | GDPGR | GDPGR |
| Constant | 3.695*** | 3.513*** | 0.622*** | 4.367*** | 1.660*** | 0.684*** |
| | (51.35) | (21.42) | (23.52) | (24.92) | (18.67) | (16.66) |
| lnFinSI(-1) | 0.044 | 0.821*** | 0.886*** | 0.244*** | 0.709*** | 0.107*** |
| | (2.76) | (156.17) | (165.89) | (4.36) | (91.55) | (18.20) |
| GDPGR | 0.056*** | 0.077*** | 0.010* | 0.286 | 0.068*** | 0.016*** |
| | (7.43) | (7.18) | (2.16) | (4.86) | (20.40) | (34.80) |
| FDevI | 0.159** | | 0.145*** | 0.033** | | 0.168*** |
| | (2.84) | | (20.57) | (2.86) | | (4.14) |
| GDPGR × FDev | 0.049*** | | | 0.009* | | |
| | (4.61) | | | (1.81) | | |
| REQua | | 0.051*** | 0.798*** | | 0.034** | 0.021*** |
| | | (4.73) | (19.33) | | (2.10) | (4.29) |
| GDPGR × REQua | | 0.002** | | | 0.080*** | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | (2.52) | | | (5.22) | |
| GDPGR × FDevI× REQua | | | 0.006** | | | 0.004*** |
| | | | (2.36) | | | (5.71) |
| PoS | 0.012* | 0.764*** | 0.748** | 0.011* | 0.014*** | 0.003** |
| | (1.86) | (217.46) | (2.74) | (1.70) | (4.22) | (2.11) |
| ATech | 0.003*** | 0.019*** | 0.020*** | 0.004*** | 0.091*** | 0.074*** |
| | (4.93) | (4.60) | (5.82) | (4.49) | (7.87) | (14.19) |
| lnTop | -0.093*** | -0.118*** | -0.124*** | -0.072*** | -0.008*** | -0.086*** |
| | (-7.22) | (-27.93) | (-7.66) | (-4.72) | (-14.54) | (-6.80) |
| Net Effect | 0.737 | 0.076 | 0.008 | 2.863 | 0.010 | 0.015 |
| Year Fixed Effect | Yes | Yes | Yes | Yes | Yes | Yes |
| Country Fixed Effect | Yes | Yes | Yes | Yes | Yes | Yes |
| AR(1) | (0.6834) | (0.240) | (0.272) | (0.2653) | (0.102) | (0.078) |
| AR(2) | (0.5760) | (0.183) | (0.792) | (0.1736) | (0.759) | (0.141) |
| Sargan Test | (0.0753) | (0.085) | (0.796) | (0.2653) | (0.738) | (0.916) |
| Hansen Test | (0.1873) | (0.726) | (0.863) | (0.3763) | (0.735) | (0.572) |
| Wald $\chi^2$ | 465.13*** | 569.53*** | 384.39*** | 119.19*** | (0.772) | (0.986) |
| Instruments | 22 | 22 | 22 | 24 | 24 | 24 |
| Country | 47 | 47 | 47 | 47 | 47 | 47 |
| Observations | 792 | 792 | 792 | 742 | 742 | 742 |

*Note(s): ***,**,* signify 1%, 5% , 10% significance levels respectively. lnCChI: Natural logarithm of Climate change Index, lnFinSI: Natural logarithm of Financial Stability Index, GDPGR: Gross Domestic Product Growth Rate: REQua: Regulatory Quality, FDevI: Financial Development Index, lnTop: Natural logarithm of Trade openness, ATech: Access to Technology, PoS: Political Stability. Mean of FDev is 0.363 and REQua is -0.729.*

#### *4.7.5.1 Relationship between economic growth and financial stability*

The regression analysis presented in table 4.14 uncovers significant trends and unanticipated associations among the variables that impact the financial stability of countries in SSA. Despite its magnitude, the initial effect of the lagged financial stability index is quite unexpected. This suggests a degree of inertia or persistence in the region's financial systems, as it indicates that past levels of financial stability continue to influence current levels (Elsayed, 2020). Consistent with conventional wisdom, economic expansion has a substantial and positive effect on financial stability ($\beta$ =0.056, 0.077, 0.010, $p<0.01$). Although statistically significant, the coefficients indicate that economic development has a marginal influence on financial stability in SSA nations (Ma, 2020).

#### *4.7.5.2 Moderating influence of financial development on the relationship between economic growth and financial stability*

Significant and positive coefficients associated with the financial development index ($\beta$=0.159, 0.145, $p<0.01$) account for the unexpected finding. Preceding

initial hypotheses of a positive correlation between financial development and financial stability, the results indicate that financial sector development has a more pronounced impact on stability than was previously known (Tsuchiya, 2023).

*4.7.5.3 Moderating influence of regulatory quality on the Relationship between economic growth and financial stability*

Robust and statistically significant coefficients (β=0.051, 0.798, p<0.01) indicate that regulatory quality significantly influences financial stability. These finding challenges conventional wisdom and underscore the critical significance of effective regulatory frameworks in fostering financial stability in SSA countries.

*4.7.5.4 Joint moderating influence of financial development and regulatory quality on the relationship between economic growth and financial stability*

The joint interaction effects of financial development index, regulatory quality, and economic growth present a complicated finding. The positive and significant interactions (β=0.049, 0.002, p<0.01) among financial development, regulatory quality, and economic growth indicate a non-linear relationship in their collective impact on financial stability.

Trade openness has an adverse effect on financial stability, while technological access and political stability contribute positively to it. The unanticipated correlations underscore the complex interplay between political, technical, and economic factors that impact the outcomes of financial stability in SSA countries. The net effect values (β=0.737, 0.076, 0.008) suggest that the examined variables collectively have a positive impact on the financial stability of countries in Sub-Saharan Africa. Unanticipated patterns and ambiguous correlations have surfaced, underscoring the necessity for further research to comprehend the fundamental mechanisms at play and develop more efficacious policy interventions aimed at bolstering regional economic growth and ensuring financial stability.

*4.7.5.5 Sensitivity analysis and robustness testing*

The analysis compares the baseline model with sensitivity and robustness testing models using system GMM, difference GMM and random effect models

Table 4.13 Random Effect Results on Economic Growth, Financial Development, Regulatory Quality and Financial Stability

| Variable | Dependent Variable: lnFinSI | | |
|---|---|---|---|
| | Sensitivity and Robustness Testing Models | | |
| | Random Effect | | |
| | (7) | (8) | (9) |
| | GDPGR | GDPGR | GDPGR |
| Constant | 3.307*** | 0.295*** | 0.327*** |
| | (99.89) | (15.02) | (6.68) |
| GDPGR | 0.067*** | 0.036*** | 0.034*** |
| | (2.46) | (80.23) | (8.75) |
| FDevI | 1.966*** | | |
| | (16.74) | | |
| GDPGR × FDevI | 0.488*** | | |
| | (14.09) | | |
| REQua | | 1.474*** | 0.001*** |
| | | (5.62) | (3.47) |
| GDPGR × REQua | | 0.533*** | |
| | | (14.12) | |
| GDPGR × FDev× REQua | | | 0.963*** |
| | | | (10.34) |
| PoS | 0.005* | 0.684*** | 0.014*** |
| | (1.82) | (7.90) | (2.84) |
| ATech | 0.002*** | 0. 843*** | 0.003** |
| | (3.50) | (13.13) | (36.88) |
| lnTop | -0.041 | -0.042 | -0.035*** |
| | (-2.46) | (-0.440) | (-10.88) |
| Net Effect | 0.244 | -0.353 | -0.221 |
| Year Fixed Effect | Yes | Yes | Yes |
| Country Fixed Effect | Yes | Yes | Yes |
| Wald $\chi^2$ | 925.32*** | 873.43*** | 914.98*** |
| Country | 47 | 47 | 47 |
| Observations | 838 | 838 | 838 |

*Note(s): ***,**,* signify 1%, 5% , 10% significance levels respectively. lnCChI: Natural logarithm of Climate change Index, lnFinSI: Natural logarithm of Financial Stability Index, GDPGR: Gross Domestic Product Growth Rate: REQua: Regulatory Quality, FDevI: Financial Development Index, lnTop: Natural logarithm of Trade openness, ATech: Access to Technology, PoS: Political Stability. Mean of FDev is 0.363 and REQua is -0.729.*

The analysis depicted in Table 4,15 compares the baseline model with sensitivity and robustness testing models using system GMM, difference GMM and random effect models. The baseline model shows a significant positive effect of GDP growth rate on the financial stability index. The sensitivity and robustness testing models consistently demonstrate a positive association between financial stability and economic development, indicating robustness. Furthermore, the inclusion of regulatory quality and financial development index in the sensitivity

and robustness testing models reveals their significant positive effects on financial stability, suggesting their importance in enhancing financial stability in SSA.

The analysis also delves into the relationships between GDP growth rate and financial development index and economic growth and regulatory, shedding light on the intricate connections between financial development, regulatory quality, and financial stability. These elements work synergistically to improve financial stability, with their impacts varying across models. Moreover, incorporating trade openness, political stability, and access to technology into the models provides a more comprehensive examination of variables influencing financial stability. While most factors have a positive impact on financial stability, trade openness shows a negative effect.

The sensitivity and robustness tests underscore the significance of regulatory quality, economic growth, and financial development in bolstering financial stability in SSA countries. The consistent results across various scenarios enhance the reliability of the conclusions, offering valuable insights for policymakers and professionals seeking to strengthen financial stability in the region.

*4.7.5.6 Further sensitivity analysis and robustness testing using quantile regression*

Further robustness testing and sensitivity analysis were conducted utilising quantile regression to examine the correlation between regulatory quality, financial stability, economic growth, and financial development across different quantiles of the financial stability index. As shown in Table 4.16, the results contain a multitude of insightful patterns and insights.

Table 4.14 Quantile Regression Results on Economic Growth, Financial Development, Regulatory Quality and Financial Stability

| | **Dependent Variable:** lnFinSI | | | | |
|---|---|---|---|---|---|
| | **Q.10** | **Q.25** | **Q.50** | **Q.75** | **Q.90** |
| Constant | 1.255$^{*}$ | 1.241$^{***}$ | 1.873$^{*}$ | 1.917$^{***}$ | 3.604$^{***}$ |
| | (0.034) | (0.000) | (0.014) | (0.000) | (0.000) |
| GDPGR | -0.188$^{***}$ | 1.032 | -0.862$^{***}$ | -0.065 | -0.466$^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.798) | (0.000) |
| FDevI | 0.209$^{***}$ | 0.702$^{***}$ | 0.722$^{***}$ | 0.679$^{***}$ | 0.592 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| GDPGR × FDevI | -0.929$^{***}$ | -1.032$^{***}$ | -0.065$^{***}$ | -0.171$^{**}$ | -0.383$^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.004) | (0.000) |
| REQua | -0.354$^{***}$ | -0.239$^{***}$ | 0.268$^{*}$ | 0.467$^{***}$ | 0.209$^{***}$ |
| | (0.000) | (0.000) | (0.015) | (0.000) | (0.000) |
| GDPGR × REQua | 1.074$^{***}$ | 0.119 | 0.413$^{*}$ | 0.275$^{**}$ | 0.683$^{*}$ |
| | (0.000) | (0.260) | (0.015) | (0.001) | (0.043) |

| | | | | | |
|---|---|---|---|---|---|
| GDPGR × FDev× REQua | 0.288*** | -0.264* | 0.813*** | 0.106* | 0.481*** |
| | (0.000) | (0.060) | (0.000) | (0.005) | (0.000) |
| PoS | -0.357*** | 0.138* | 0.107** | 0.237* | -0.154 |
| | (0.000) | (0.054) | (0.001) | (0.020) | (0.166) |
| ATech | -0.175 | -0.167* | -0.091** | 0.214* | -0.291** |
| | (0.570) | (0.006) | (0.001) | (0.075) | (0.002) |
| lnTop | 0.188*** | -0.236*** | 0.111* | 0.175** | -0.097** |
| | (0.000) | (0.000) | (0.052) | (0.004) | (0.001) |
| Gini Index | -0.195*** | 0.194*** | -0.046*** | 0.480*** | -0.304* |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.016) |
| Pseudo $R^2$ | 0.748 | 0.543 | 0.439 | 0.725 | 0.803 |
| Observation | 839 | 839 | 839 | 839 | 839 |

*Note(s): ***,**,* signify 1%, 5% , 10% significance levels respectively. p-values are in parenthesis. lnCChI: Natural logarithm of Climate change Index, lnFinSI: Natural logarithm of Financial Stability Index, GDPGR: Gross Domestic Product Growth Rate: REQua: Regulatory Quality, FDevI: Financial Development Index, lnTop: Natural logarithm of Trade openness, ATech: Access to Technology, PoS: Political Stability, Gini Index: Income Distribution.*

The economic growth (GDP growth rate) exhibits variation among different quantiles. At the 10th and 50th quantiles, the impact of economic growth is consistently negative and substantial; however, at the 75th and 90th quantiles, it becomes negligible, indicating a nonlinear relationship between financial stability and economic growth at varying stability levels. At all quantiles, the financial development index has a consistent and significant positive effect on financial stability suggesting that greater financial stability is associated with improved financial development.

The effects of the correlation between economic growth and financial development index vary across quantiles. At the 10th and 25th quantiles, the interaction term is significant and negative, indicating that greater financial development attenuates the correlation between financial stability and economic growth. The interaction term exhibits a positive and statistically significant relationship at the 75th and 90th quantiles, suggesting that economic growth and financial development have a more pronounced effect on financial stability. Furthermore, the effects of regulatory quality differ across quantiles. At the lower quantiles (10th and 25th), the principal effect of regulatory quality is negative and statistically significant. However, as the quantiles increase to the 75th and 90th, the trend changes to positive and statistically significant. This suggests a complex relationship between financial stability and regulatory quality.

The incorporation of supplementary factors such as income distribution (Gini Index), political stability, and access to technology into the quantile regression

models provides novel perspectives. The fact that political stability and access to technology have distinct effects on financial stability at different quantiles illustrates the nuanced relationship between technical access and financial stability and political stability. Indicating the importance of income equality in fostering financial stability, the Gini index, which measures income distribution, influences financial stability significantly at the 10th, 25th, and 75th quantiles. The quantile regression analysis offers a comprehensive examination of the relationship between financial development, regulatory quality, economic growth, and financial stability across different levels of stability. The findings highlight the intricate and diverse characteristics of this correlation, underscoring the necessity for tailored policy interventions to bolster financial stability in various Sub-Saharan African economic contexts.

#### ***4.7.5.7*** *Discussion on the relationship between financial development, regulatory quality, economic growth and financial stability*

The discussion covers the direct relationship between economic growth and economic growth, moderating influence of financial development and regulatory quality and the joint moderating influence of financial development and regulatory quality on the relationship between economic growth and financial stability. In the exploration of the complex relationship among financial development, regulatory quality, economic growth, and financial stability, descriptive statistics serve as a crucial foundation for empirical analysis (Zhang & Wei, 2023). Financial development, characterized by the expansion and diversification of financial services, has shown a positive correlation with economic growth, enhancing financial stability across SSA. This relationship is underscored by the facilitation of more resilient financial systems that can better absorb economic shocks and manage risks more effectively. Regulatory quality plays an indispensable role in this framework, ensuring that financial growth does not outpace the supervisory capacity of financial institutions. High regulatory standards maintain market discipline and investor confidence, which are vital for sustainable economic growth and financial stability (Canguende-Valentim et al., 2024).

The empirical research suggests that robust regulatory frameworks enhance the effectiveness of financial markets by reducing information asymmetry and

controlling excessive risk-taking behaviors. Economic growth contributes to financial stability by expanding the resources available for investment in technology and infrastructure, which are necessary for supporting comprehensive financial services (Asante et al., 2023). However, without the moderating effect of sound financial development and strict regulatory oversight, rapid economic growth can lead to financial instability due to asset bubbles and speculative investments.

The regression analysis conducted in this study offers important perspectives into the complex interplay of financial stability among countries in SSA. The findings unveil significant correlations and unexpected associations that deviate from the initial hypotheses. The lagged financial stability index has exhibited an unforeseen effect, indicating that the region's financial systems continue to be troubled. The enduring influence of past levels of stability on current levels provides support for Elsayed (2020) concept of inertia in financial systems. Historical context and temporal dynamics must be considered when assessing the financial stability of countries in Sub-Saharan Africa.

Disturbing revelations regarding the correlation between financial stability and economic development emerge from the investigation. The analysis challenges the prevalent notion that a robust positive correlation exists between financial stability and economic growth (Atellu & Muriu, 2022). Although economic growth has a positive effect on financial stability, the extremely small magnitude of the coefficients, particularly in countries like Nigeria with a booming but young financial sector, casts doubt on the robustness of this relationship for all SSA countries. The existing discrepancy requires a revaluation of prevailing assumptions and emphasizes the importance of possessing a comprehensive understanding when examining the impact of economic factors on financial stability (Atellu & Muriu, 2022). The unexpected findings also highlight the importance of acknowledging potential data processing challenges arising from the diverse data conditions across SSA countries. Different income levels and data collection methods might introduce inconsistencies that could influence the results. For instance, relying on surveys for financial stability data in a country like Malawi might yield different results compared to countries with more established financial reporting systems like Mauritius.

The regression analysis unites strong coefficients that underscore the critical importance of the financial development index in SSA countries for the promotion of financial stability. The strong coefficients for the financial development index highlight its role in stability. Countries like Kenya which have seen significant growth in their FinTech sectors in recent years can benefit from further financial development initiatives. Tsuchiya (2023) found that the expansion of the financial sector significantly contributes to the enhancement of financial stability, which is consistent with the present conclusion. As previously acknowledged, the strong coefficients indicate that improvements in financial development have a more substantial impact on stability (Bernards & Campbell-Verduyn, 2019). This underscores the critical role that robust financial institutions and markets play in promoting stability.

The study demonstrates significant associations with regulatory quality, underscoring the critical significance of effective regulatory frameworks in preserving financial stability in countries located in SSA. These findings are consistent with those of (Ma, 2020), which emphasise the significance of transparent and efficiently executed regulatory processes in safeguarding financial systems. This is crucial for safeguarding financial systems in SSA countries, like Ghana which is working on improving its regulatory environment for the FinTech sector. Regulation can mitigate moral hazard, rectify information asymmetries, and enhance market integrity, all contributing to financial stability (Jungo et al., 2022). The study revealed a complex relationship between financial stability in SSA countries and the combined effects of the financial development index, regulatory quality, and economic growth. Despite initial assumptions, the interactions reveal a nonlinear relationship that necessitates additional investigation into the collective impact on financial resilience (Athari, 2024; Noor et al., 2021). This finding lends credence to the notion that the dynamics of financial stability are influenced by a multitude of interdependent forces, as perceived by various authorities.

Unanticipated associations are uncovered in the study, including the adverse consequences of trade openness on financial stability and the advantageous effects of technical access and political stability (Ngalawa & Derera, 2023). The unexpected results underscore the intricate interplay between various socio-

economic and political factors that influence the financial stability of countries in SSA. Notwithstanding the economic benefits that globalisation has engendered, trade openness may potentially expose financial institutions to risk, which could result in adverse outcomes. On the contrary, the positive effects of political stability and the accessibility of technology highlight the importance of unconventional economic factors in shaping financial resilience (Oanh, 2023).

The utilisation of quantile regression analysis revealed that economic development exhibited varied effects across different quantiles, indicating the existence of a non-linear correlation with financial stability. Consistently, the financial development index demonstrates a substantial positive effect on financial stability across all levels, underscoring its function in promoting stability (Giordino & Revello, 2023). The interaction between economic growth and the financial development index across quantiles reveals that correlations vary with the degree of stability in question. This underscores the complex relationship between financial stability and regulatory quality, as the effects of regulatory quality differ across levels.

The literature review offers valuable insights into the intricate interplay among financial development, regulatory quality, economic growth, and financial stability. It establishes a solid theoretical foundation that serves as the foundation for the research's conclusions. Allioui and Mourdi (2023) and Phan et al. (2021) have conducted research that underscores the criticality of robust regulatory frameworks and robust financial institutions in mitigating the adverse consequences of economic instability on financial security. These studies underscore the importance of establishing resilient financial institutions and uniform regulatory frameworks to ensure stability in the face of economic fluctuations. The strong correlations observed between regulatory quality and the financial development index in this study are consistent with results obtained in prior investigations.

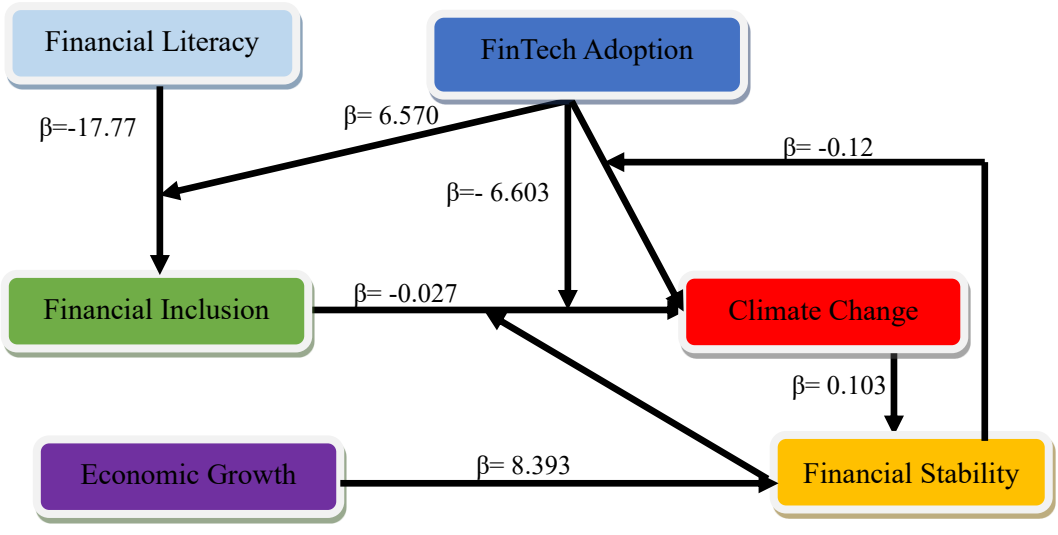
While previous research provides valuable perspectives, the empirical evidence remains equivocal on multiple fronts. Despite significant findings regarding the relationship between financial development, regulatory quality, and financial stability, there are still knowledge deficits regarding the complete interplay between these variables. This underscores the necessity for further empirical research to

examine the complex dynamics at play. Critical to understanding the relationship between financial stability and its determinants are contextual variables and institutional diversity, according to the literature review. The results of this study contribute to the existing body of knowledge by providing empirical evidence that substantiates the theoretical underpinnings proposed in previous research. It is imperative to acknowledge the limitations and potential biases inherent in empirical inquiries, as these can significantly influence the interpretation of results.

In summary, despite its limitations, this study provides valuable insights into the factors that influence financial stability in Sub-Saharan African countries. Methodological constraints, biases, and potential threats to internal validity are all potential study flaws. The findings contribute to the existing body of knowledge by uncovering unanticipated relationships and highlighting the complex interplay of numerous factors that influence financial stability, despite specific limitations. Further research should strive to address these constraints and explore the complex interrelationships among financial development, regulatory quality, economic growth, and financial stability. By doing so, it is possible to inform policy measures that have a greater influence and promote sustainable economic advancement in Sub-Saharan African nations.

**4.8 Novelty**

The research delves into unexplored areas concerning economic growth, climate change, and financial considerations in SSA countries. It challenges traditional viewpoints by revealing intricate dynamics among these variables, prompting a re-evaluation of established frameworks.



β=-0.012

Figure 4.1 Novelty Model-Major Contribution

Source: Author' Construct (2024)

The study delves into unexplored areas concerning economic growth, climate change, and financial considerations in SSA countries. It challenges traditional viewpoints by revealing intricate dynamics among these variables, prompting a re-evaluation of established frameworks. The study uncovers unexpected interconnections between FinTech adoption, financial stability, and climate change, highlighting the complexity of their relationship. It emphasizes the need for a deeper understanding of how FinTech adoption influences financial stability and, consequently, impacts climate resilience. By offering fresh insights into the interplay between financial stability, economic development, and the effects of FinTech adoption on climate change, the research contributes to expanding the current knowledge base and setting a foundation for further exploration in this emerging field.

The theoretical framework of the study provides a solid basis for analyzing the complex relationships between financial issues, climate change, and economic growth in SSA countries. By incorporating various theoretical perspectives such as development finance, financial inclusion theory, and economic development theory, the research offers a comprehensive understanding of climate resilience and financial inclusion in the region. The study aligns with the concept of development finance by highlighting the influence of structural elements on financial stability in SSA countries. It identifies a non-linear relationship between financial development, regulatory quality, and financial stability, emphasizing the systemic dynamics at play.

The integration of middle-range theories like financial inclusion theory, economic development theory, and social learning theory enriches the investigation into the interplay between climate change, FinTech adoption, and financial stability. These theories shed light on the interdependence of stakeholders in advancing

climate resilience and financial inclusion. Additionally, applied theories such as innovation diffusion theory, climate change adaptation theory, and FinTech adoption theory provide practical frameworks for analyzing the adoption of financial technologies and adaptation strategies in the face of climate change.

The study's theoretical framework enhances the understanding of the complex relationships between financial matters, climate change, and economic development in SSA countries. By establishing connections between key findings and theoretical perspectives, the research offers a comprehensive framework for analyzing the determinants and consequences of climate resilience and financial inclusion in the region. This framework equips policymakers and stakeholders with essential information to promote financial stability and sustainable development effectively.

The primary contribution of the study lies in its thorough investigation of the interplay among financial concerns, climate change, and economic expansion in SSA countries. It goes beyond merely identifying correlations by uncovering overlooked mechanisms and unexpected connections, thereby enriching the discourse on the topic. The research sheds light on the potential impacts of technological advancements in emerging economies, particularly how FinTech adoption could reshape financial structures. The implications of the study's findings for policymakers and practitioners emphasize the need for tailored policy initiatives that address the unique challenges and opportunities in SSA countries to promote sustainable development and financial stability.

The Novelty Model-Major Contribution framework employed in this research offers innovative perspectives and advancements in the field. By exploring novel concepts, elucidating theoretical frameworks, and presenting significant findings, the study enhances our understanding of the complex interrelationships between financial matters, climate change, and economic development in SSA countries. These insights can guide the formulation of research agendas and policy interventions to advance environmental sustainability and equitable growth in the region. The specific novelties are:

1. This study examines a new area in Sub-Saharan Africa: the connections between financial stability, climate change, and FinTech adoption.
2. It challenges traditional thinking by revealing surprising links between these factors, particularly the complex role of FinTech.
3. The research provides a new framework to understand these relationships and inform policymakers.
4. This fresh perspective can guide future research and policy decisions for sustainable development and financial stability in the region.

### 4.9 Best Model for SSA Countries

Based on the study findings, one promising model focuses on the moderating effect of financial stability on the FinTech-climate change relationship. This model incorporates an interaction term that reveals how a stable financial environment strengthens FinTech's positive impact on combating climate change. This aligns with the study's finding that FinTech's influence is more potent when financial stability is present.

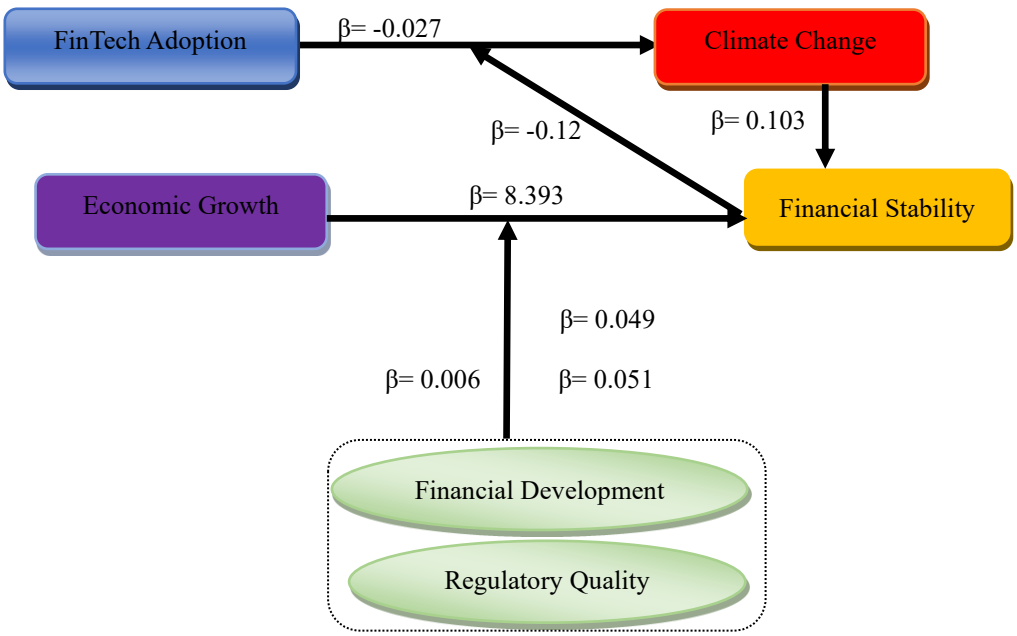



Figure 4.2 Best Model for SSA Countries

Source: Author' Construct (2024)

Another robust element of the best model for SSA countries highlights the crucial role of financial development. This model likely demonstrates a robust positive association between a well-developed financial sector and financial stability, supported by statistically significant coefficients. This finding emphasizes that fostering a robust financial sector can significantly enhance stability in SSA countries, potentially more so than previously thought. Finally, a model emphasizing regulatory quality also stands out. This model showcases a surprisingly strong positive association between effective regulations and financial stability. This challenges initial expectations and underscores the importance of well-designed regulations in fostering financial stability within the unique context of SSA countries.

This model is considered "best" because they possess several key strengths. First, the model is statistically robust, with significant results indicating the observed associations are unlikely due to chance. Second, the model captures the unexpected relationships identified in the study, such as the moderating effect of financial stability or the crucial role of regulatory quality. A "best" model needs to account for these distinctions specific to SSA countries. Finally, the model demonstrates strong explanatory power within the specific context of this region. The statistical results show that this model effectively capture the unique interplay of factors influencing financial inclusion, FinTech adoption, financial stability, economic growth, and climate change in SSA countries, differentiating them from models applicable to other regions.

Overall, this study confirms the hypothesis that financial inclusion and FinTech adoption show potential in combating climate change by enabling investments in sustainable practices. Greater financial inclusion empowers individuals and businesses to make climate-resilient investments, while FinTech adoption facilitates such investments. Financial stability strengthens FinTech's impact on promoting climate-resilient solutions. The relationship between financial stability and climate change is complex, with both positive and negative correlations observed. Financial stability can help countries mitigate climate change impacts, but it also correlates positively with climate change severity, possibly due to proactive measures taken by countries facing climate challenges.

Economic growth has a dual impact on climate change, providing resources for adaptation efforts but also contributing to the problem through increased production and emissions. The study confirms the expected positive relationship between economic growth and financial stability, emphasizing the need for additional factors like a well-developed financial sector to enhance this relationship in SSA countries. Financial development emerges as a significant contributor to financial stability, highlighting the importance of a well-developed financial sector in enhancing stability. Regulatory quality also plays a crucial role in fostering financial stability, contrary to expectations, with effective regulations being essential for stability in SSA countries.

The study confirms complex interactions between financial development, regulatory quality, and economic growth in their impact on financial stability. A non-linear relationship is suggested, where all three factors must be considered for optimal outcomes. Trade openness, technological access, and political stability also influence financial stability, underscoring the multifaceted nature of this concept in SSA countries. Thus, the study underscores the interconnectedness of financial inclusion, FinTech adoption, financial stability, economic growth, and climate change in SSA countries. Policymakers can leverage these findings to design holistic strategies that promote sustainable development, enhance financial stability, and combat climate change in the region. The study's insights provide a nuanced understanding of the factors at play and offer a roadmap for policymakers to navigate the complex landscape of financial inclusion and sustainability in SSA countries.

Thus, the best model for SSA countries is:

**a)** A stable financial system strengthens the positive impact of FinTech on combating climate change. **b)** well-developed financial sector significantly enhances financial stability and **c)** effective regulations are important for financial stability in SSA countries.