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The Role of Fintech, Green Finance and Innovation Towards Sustainable Performance: Evidence Form Pakistan's Banking Sector with IT Governance as a Moderator

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Abstract: *The impact of FinTech Adoption integration on the banking sector has spurred its rapid integration and has helped in the financial sustainability through efficiency, financial inclusion and environmentally responsible banking. The research seeks to contribute to the empirical understanding of how initiatives driven by FinTech Adoption can contribute to sustainability in financial institutions in a developing economy. The research design is quantitative and Structural Equation Modeling (SEM) is applied to verify the hypothesized relationship. Structured questionnaire was used, which was based on essential existent data gathered from 368 banking professionals including operational and branch managers. To have a representative sample of the banking sector, a cluster sampling technique was used to ensure that banks from different regions of Pakistan and from various financial institutions were represented. The results of the study prove that the use of FinTech adoption, green finance and green innovation has a significant effect on the sustainability of Pakistan's banking sector. In addition, both green finance and green innovation play a significant role in the link between using FinTech adoption and sustainability. Yet, the results did not show a significant impact of IT governance in the relation between FinTech adoption and sustainable performance. The study contributes to the fact that the findings highlight the necessity that financial institutions and policymakers should enhance the green financial products, implement financial technology for sustainability tracking, and integrate the technology driven risk assessment models. It further implies that it is necessary to restructure IT governance frameworks that support sustainability objectives instead of strictly compliance.*

Keywords: FinTech Adoption, Green Finance, Sustainable performance, Green Innovation, IT Governance

1. Introduction

Banking sectors has a significant role in the growth and development of the economy, industry and individual. A new technological advancement revolution has been initiated due to the sustainability issues facing the contemporary world (Lisha, 2023; Rais, 2023). Thus, in the context of achieving competitiveness and sustained performance in the banking business, it becomes imperative for banks to create new forms of processes and services in order to create value for stakeholders (Ho et al., 2009). The implementation of modern technology enabled products and services for the stakeholders and services can also help in growth (Sharma & Riya, 2022). Therefore, the banking technology in banking goods and services has revolutionized the banking industry.

Digital technologies now change how businesses work as well as reframe how they compete to create value. These changes matter more in Pakistan because emerging businesses need to switch from traditional methods to technology-based ways of doing business (Imran et al., 2023; Melati et al., 2024). One of the major breakthroughs is the rise of Financial Technology (FinTech), integrating the financial services business with the digital innovation to make banking operations a lot more efficient, accessible, and sustainable.

Nearly 18 to 24-year-old people across Pakistan are choosing digital platforms and mobile apps to handle their money (Volosovych et al., 2024). Digital bank services and AI technology help all people gain access to banking services including those without traditional accounts. (Anan et al., 2023) forecasts rapid digital finance growth will happen across emerging markets including Pakistan. The digital transformation opens new ways for financial institutions to run operations better while making positive social and environmental impact.

The poor scores that Pakistan achieves on innovation and environmental performance rankings mean its banks need to start adopting sustainable practices immediately. Financial technology tools make it possible to achieve this change. These technologies enable green banking practice through better resource management and help conserve natural resources (Firdos et al., 2024). The World Economic Forum (2024) emphasizes that sustainable development goals must be part of every FinTech growth effort thanks to their new report.

Sustainable performance in banking includes the striving to long-term economic, environmental and social performance. It's beyond profit maximization and includes good lending, low environmental impact, and fair access to financial services (Busch et al., 2024; Franco et al., 2024). The triple-bottom-line framework continues to strengthen in importance because stakeholders insist on sustainable measurements in environmental social governance (ESG) aspects.

However, the issue of economic growth and environmental sustainability remains an issue that is of global concern and has necessitated the adoption of comprehensive strategies such as technological innovation for sustainable development (Awawdeh, 2021; Ozturk et al., 2022). Among these innovations, Financial Technology (FinTech) and Green Finance (GF) are among the most popular innovations, especially after the COVID-19 pandemic has accelerated the digital transformation (Xie, 2021).

One of the examples regarding this integration of technology and sustainable practices is the evolution of the financial technology, or FinTech which currently transforming the financial industry (Atayah, 2023; Cruz et al., 2023; Lisha, 2023). The governments of the world have taken a number of actions in the direction of green finance and sustainable banking to enhance environmental sustainability (Guang-Wen, 2022; Zheng, 2021). Digitalization helps creating sustainable economies by endorsing comprehensive progress and reaching greater efficiency, and promoting online banking and trade.

Recently, research on the association between green finance and sustainability has focused on activities on fintech and green finance. Additionally, the use of a credible and efficient digital payment system on both nationwide and cross border levels is a central approach for reducing disparity and sustainability (Guang-Wen, 2022). As Nassiry and Darius (2018) states, regulators in developing countries need FinTech and green finance to help them meet the Paris Agreement and SDGs. In the course of achieving the country's sustainable development, banking institutions have adopted innovative technologies, such as blockchain, green banking, and online banking (Siddik, 2021), and have been sponsoring a lot of eco-friendly initiatives like, clean energy, clean technology, energy efficiency and green industrial development.

The country of Pakistan remains in the grip of substantial sustainability problems. The Environmental Performance Index (EPI) positioned Pakistan at the 169th rank in 2023 because of critical environmental issues across climate policy, air quality and ecosystem health (Contreras et al., 2023).

The national environmental performance ranking of 169th demonstrates the crucial requirement for Pakistan's economic engine sectors to take increased action for environmental sustainability projects.

Current trends in financial technology (FinTech) transform traditional banking operations through its creation of more rapid financial services that are accessible to all and operate at reduced costs (Gomber et al., 2018). Digital payments together with blockchain transparency tools and AI risk management systems through FinTech applications transformed banking interactions and resource management for customers (Arner, 2020). The priority of financial inclusion development in Pakistan makes FinTech solutions highly promising to improve efficiency while expanding accessibility and driving economic and social advancement (Ahmed, 2024a, 2024b).

Although Pakistani banks show potential for FinTech integration they have not yet achieved sufficient adoption of sustainable digital solutions. The current governance systems of various institutions hold onto traditional structures which fail to support modern ESG requirements (Dwivedi, 2021). The substantial gap highlights an important need to determine how FinTech adoption strategies should combine operational efficiency improvements with sustainable economic social and environmental performance advancements.

The banking sector needs to develop governance guidelines for digital transformation that unite environmental responsibilities (Al-Sartawi et al., 2020; Scalabrin Bianchi et al., 2021). These challenges include insufficient digital infrastructure alongside resistance to change and insufficient readiness from regulators which block this transition in Pakistan. Studies should focus on understanding how FinTech together with green finance and innovation systems can lead to sustainable results in Pakistan's banking industry. Hence the objective of the study is to:

RO1: To analyze the impact of FinTech adoption on the sustainable performance in Pakistan’s banking sector.

RO2: To evaluate the influence of FinTech adoption on green finance and green innovation in Pakistan’s banking sector.

RO3: To explore the effects of green finance and green innovation on the sustainable performance banking sector in Pakistan.

RO4: To investigate the mediating roles of green finance and green innovation in the relationship between FinTech and sustainable performance in Pakistan’s banking sector.

RO5: To examine the moderating role of IT governance in enhancing the relationship between FinTech adoption and sustainable performance in Pakistan’s banking sector.

The business world is undergoing a series of dramatic changes accelerated by technological developments (Stauropoulou et al., 2019). Climate change is having a huge impact on financial systems and financial institutes are trying to make sure environmental, social and governance issues that lead to sustainable growth (Park et al., 2020). Banks have a dominant position in the financial system and their credit management should support businesses that promote green business initiatives and undertaking green environmental management technology (Dörry et al., 2018).

In the green banking initiatives of the emerging All the financial actions that try to reduce the environmental destruction would be included in Go Green period. It also finds that online banking (Khan & Ullah, 2022) and the issuance of green loans (Giraudet et al., 2021) are two of the green banking practices that have been identified.

Thus, this research investigates multiple gaps by studying the relationship between FinTech adoption and sustainable performance in Pakistani banks through green finance and green innovation mechanisms under IT governance conditions. An examination of FinTech adoption's direct influence on sustainable performance in Pakistan's banking sector. This research examines green finance and

green innovation as intermediaries between FinTech adoption and sustainable performance results. This analysis uses IT governance as a moderating variable to examine how governance practices affect FinTech sustainability potentials.

2. Literature Review:

2.1 FinTech Adoption and Sustainable Performance

The Financial technology, or FinTech, has a transforming role in changing the way people and entrepreneurs operate their financial affairs. FinTech improves the efficiency, access, and accuracy of financial services at multiple levels of participation in the economy harnessed through the use of artificial intelligence (AI) and other state of the art technologies.

FinTech not only enhance the financial operations and decision-making for the users, but also ensures the achievement of other objectives such environmental sustainability (Udeagha & Muchapondwa, 2023). The incorporation of contemporary technological tools in the financial sector has turned the old ways of doing business upside down, and with a lot of speed, security, and reduced dependence on physical infrastructure. This evolution is especially favorable to populations which were previously left out by traditional financial institutions thus making financial inclusion possible. Besides enhancing individual and organizational financial management, FinTech has also proved its ability to function as a pusher of sustainable development.

Udeagha and Muchapondwa (2023) reveal that FinTech's digital infrastructure can be useful in adding value to the sustainability of environment. This is done through reduction in paper-based transactions and reduction in carbon footprint of financial operations. In addition, FinTech platforms promote the use of energy-efficient technologies and foster digital ecosystems that can reduce emissions by smarter allocation of resources, and remote delivery of services. FinTech is growing not only as a finance instrument but also as a strong enabler of green economics.

The effect of FinTech on economic growth is another area of research of great importance. FinTech's mediating nature plays a large role in shaping the macroeconomic landscape according to (Kabir & Sayem, 2022). From their study, they discovered that the adoption of FinTech products and services promotes economic growth by speeding up and increasing the volume of transaction and allows for better access to credit, and stimulates innovation amongst businesses. The ability of FinTech to act as a mediator and magnifier of the effects of other economic drivers makes it an essential part of development policy designed to enhance sustainable economic development. Shaukat et al. (2020) stress out the significant macroeconomic advantages of FinTech, stating that it facilitates the more efficient allocation of capital and encourages entrepreneurial activity. From the organizational point of view, the adoption of FinTech is also well documented.

The use of FinTech is a significant change in the way financial and business operations are undertaken. As evidenced the benefits of FinTech go much beyond efficiency and profitability. It is an enabler of sustainable development, economic solidity, sectoral growth and technological uptake. FinTech is set to be a corner stone of inclusive, sustainable economic growth in the digital age as more and more stakeholders identify and accept its potential (S. Firdos et al., 2024; Kabir & Sayem, 2022; Lontchi et al., 2023; Shaukat et al., 2020; Udeagha & Muchapondwa, 2023). Thus, the hypothesis:

H1: *FinTech Adoption has a positive influence on Sustainable Performance.*

2.2 FinTech Adoption, Green Finance and Green Innovation

The connection between environmental sustainability and creativity has been well researched (Kraus, 2020). Yet, studies exploring the connotation of FT, GF and GI in one study have not been much studied, especially among banking companies in emerging economies. Consequently, the current study tries to close the gap by investigating the relationships among these variables. Awawdeh (2021) have

examined the effect of GF and CSR on technical innovation and business environmental performance.

The study concludes that GF and technical innovation can significantly improve a company's environmental performance. Peng (2021) assert that GF can help regulators to optimize energy structure and promote the development of cutting-edge energy technologies and disruptive GI. GF technologies for instance big data, blockchain, and the Internet can be used by FinTech to help meet the SDGs (Siddik, 2021). In addition, the relationship between GF and GI has been mixed (Wang, 2022). GF was found to improve GI in developing nations and nations with little green financing on the one hand.

The growing body of empirical literature has thoroughly examined the dynamic relationship between Fintech adoption and the advancement of green finance, offering critical insights into its transformative capabilities. (Hou et al., 2023) emphasized that Fintech significantly enhances transparency and operational efficiency within financial systems. This improvement is not merely administrative it facilitates more informed and responsible investment decisions that channel capital toward environmentally sustainable projects, thereby accelerating the development of the green finance ecosystem.

In a complementary perspective, Liu et al. (2022) highlighted Fintech's capacity to effectively assess and filter businesses based on their environmental performance. Through data-driven evaluations and advanced analytics, Fintech platforms can identify firms that are genuinely committed to sustainable practices, thereby reducing instances of greenwashing and ensuring that financial resources are allocated to entities that align with ecological goals.

Yu et al. (2020) provided robust empirical evidence showing that the integration of Fintech has a notable impact on the proliferation of environmentally sustainable control technologies. This adoption not only boosts operational sustainability within industries but also fosters greater societal trust and enhances access to financial support mechanisms. Collectively, these findings underscore the pivotal role of Fintech in not only streamlining financial operations but also in reshaping the landscape of green finance by aligning financial flows with sustainable development priorities. Moreover, FinTech also promotes both the extent and complexity of green organizational innovation. For example, digital innovations like blockchain can be used to create systems that facilitate economic models of recycling, reuse, and circulation (Rehman Khan et al., 2022; Saurabh & Dey, 2021).

FT revolutions determined by digitalization can affect various aspects of financial services, and hence sustainability (Callsen, 2021; Guang-Wen, 2023). Studies suggest that FT lending platforms may be more favorable for environmentally friendly projects to access capital (Anshari, 2019). Studies have established that FT can decrease carbon emissions (Deng, 2019) enhance the use of renewable energy (Bayram, 2022) and increase financial inclusion (Arner, 2020).

FT is potentially able to promote green finance, according to (Agudo, 2021). FT, according to Arner (2020) can contribute to the UN SDGs, by improving the digital financial infrastructure. According to Deng (2019), FinTech and sustainable development have a U-shaped relationship. Agudo (2021) claim that digital payment systems might improve financial inclusion and stimulate socioeconomic sustainability. Thus, the hypothesis:

H2: *FinTech Adoption has a positive influence on Green Finance.*

H3: *FinTech Adoption has a positive influence on Green Innovation*.

2.3 Green Finance and Sustainable Performance

Green finance has become an important tool in the global fight to combat climate change and environmental degradation both of which are existential threats that know no borders. The growing sense of urgency of the climate crisis, highlighted by speeding biodiversity loss and increasing danger posed by the rising sea levels requires an immediate, globally coordinated action across industries and

geography (Fu et al., 2024). More than a million species are threatened with extinction as habitats are destroyed and ecosystems collapse, while communities up and down our coastlines are hit with displacement, economic insecurity, and environmental uncertainty. These pressing concerns elevate the importance of innovative financial mechanisms capable of steering economies toward a more sustainable trajectory (Yuan et al., 2021).

According to Fu et al. (2023), green finance is a transformative force that can help achieve carbon neutrality and long-term prosperity. They claim that by incorporating environmental sustainability into financial decision making, economies can be resilient and regenerating. Furthermore, the idea of the blue economy is a prime example of how green finance can help achieve sustainable development goals.

However, green finance is only one part of a larger ecosystem of sustainable development finance, which also include blue finance, addressing ocean and marine sustainability, digital finance that uses technology to achieve environmental goals and social finance and aiming at inclusive and equitable development (Cao et al., 2021). Together, these financing approaches reflect an integrated vision for sustainable development, where green financing, environmental stewardship, and social responsibility converge to shape a resilient, inclusive, and low-carbon global economy (Taghizadeh-Hesary & Yoshino, 2019).

The literature suggests that GF and its components have positive impact on SP of banking institutions (Zheng, 2021). On the other hand, prior study has revealed that GF has a constructive impact on the business environmental performance (Guang-Wen, 2022). In addition, Xu (2020) have also shown that GF significantly recovers business green performance. Green investment significantly promotes the firm's financial and SP (Shahzad, 2022). Thus, the hypothesis:

H4: *Green Finance has a positive influence on Sustainable Performance.*

2.4 Green Innovation and Sustainable Performance

GI is the term used to describe technical progress aimed at reducing waste, air pollution, environmental degradation, coal, oil, and power (Kraus, 2020). GI is important today in extenuating the harmful effects of climate change (Li, 2020). GI is also defined in this study as technical advancements in the banking sector that lower both internal and external environmental pollutants, helping banks to attain environmental sustainability. Mobile and green environmental strategies, green marketing strategies, internet banking and green banking, are among these developments. The literature of Shahzad (2022) has shown that green innovation can dramatically improve sustainability performance.

Sustainable development (SD) is largely determined by the ability of an organization to be innovative and inventive as this would allow firms to move beyond just meeting regulatory standards and move towards proactive and value-creating strategies (Chan, 2005; T. Chin et al., 2022). Rather than simply following pre-established environmental policies and standards (A. Rehman et al., 2021; S. U. Rehman et al., 2021). Organizations that adopt the culture of innovation are able to design products and implement procedures that are naturally inclined towards ecological priorities (Chen et al., 2015). .

Practically, entities like banks can direct their investment portfolios in the direction of sustainable ventures by prioritizing their funding to green innovations and resource-efficient ventures. This strategic direction not only enhances the internal efforts of financial institutions toward achieving sustainability objectives but also elevates their role as pivotal contributors in the wider ecological transition. By actively promoting sustainable finance and embedding green innovation (GI) into their long-term strategies, banks and other corporate entities can play a transformative role in advancing global sustainable development goals (Niazi et al., 2023).

While green innovation and environmentally sustainable development are new additions to the academic lexicon, they have gained ground in the discourse about sustainable development (Albort-Morant et al., 2016). As climate change, and environmental degradation are now global issues, scholars

as well as practitioners have called for the need for green innovation as an essential element of responsible business. It is now a common understanding that the move to sustainability must be facilitated by the emergence and dissemination of eco-innovations that will enhance resource efficiency, minimize environmental impact and foster social well-being.

GI is claimed by Adegbile (2017) to be linked to a company's environmental management strategy and to contribute to environmental performance. Moreover, studies have confirmed that GI significantly diminishes a organization's adverse environmental impact, and also significantly decreases a organization's waste and costs, thus improving a firm's organizational financial performance (Weng, 2015). As noted by Wang (2021b), GI and organizational performance have a good correlation. Similar to Kraus (2020), GI was shown to affect environmental performance. Thus, the hypothesis:

H5: *Green Innovation has a positive influence on Sustainable Performance*

2.5 Green Finance and Green Innovation as Mediator

The earlier examination of the relationship among FA, GF, GI, and SP shows that GF and GI are able to significantly increase the SP of the organization. We however, do not know how FA affects SP using GF and GI as the mediating factors in the context of financial institutions (Yan, 2022). As such, the current study tries to fill the gap in the research literature by investigating the link among these variables in the context of a banking operations in an developing country. Zhang (2022) recently examined the consequence of green banking practices on banking firms' environmental performance, through the mediating effect of GF.

It was found that GF significantly mediates the association amid the environmental performance of banking firms and green banking operations. Additionally, GF is found to have a very large impact on SP (Zheng, 2021). Furthermore, GI was discovered to have substantial influence on environmental performance (Wang, 2021a). Furthermore, Kraus (2020) also found that GI has a large impact on the association between environmental performance and corporate social responsibility. Thus, the hypothesis:

H6: *Green Finance mediates the relationship between FinTech Adoption and Sustainable Performance.*

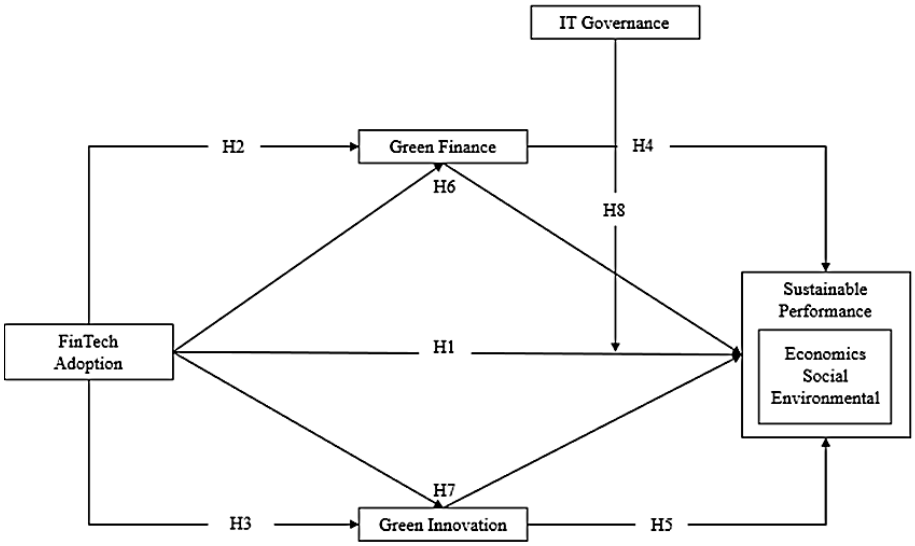
H7: *Green Innovation mediates the relationship between FinTech Adoption and Sustainable Performance.*

2.6 IT Governance as Moderator

Many research have studied the complicated link between the adoption of information technology and sustainability (Lisha, 2023; Macchiavello, 2022). The main conclusions of the study are critically discussed with regards to the implications of information technology for sustainability. ITG can reduce emissions and increase efficiency in energy but potential rebound effect should be contemplated (Robiyanto, 2021). Sahoo (2024) claim that IT's beneficial effects on sustainability should be optimized, while its unintended consequences reduced, using a sophisticated approach.

Consequently, ITG is required for performance management, value delivery and strategic formulation. Along with this it improves project performance by highlighting the importance of alignment (Sirisomboonsuk, 2018). A comprehensive strategy needed to emerge that extends beyond technological innovation; that takes into account, among other things, how equitable its distribution will be and a regulatory environment in which it will operate (Arner, 2020). Thus, the hypothesis:

H8: *IT Governance moderates the relationship between FinTech Adoption and Sustainable Performance.*



3. Methodology:

The research is aimed to determine how the adoption of FinTech affects the sustainable performance of the Pakistani banking sector, as well as to identify the mediating effects of green finance and green innovation and the moderating effect of IT governance. The research intends to evaluate the contribution of these digital and environmental innovation have a contribution towards economic, social, and environmental aspects of sustainability.

In order to fulfil this aim, the research design is a quantitative research methodology with deductive approach of research. The method is appropriate in the hypotheses guided by the literature and examination of variable relationships guided by organized data analysis.

The study target population is the managerial level employees of commercial banks in Pakistan; branch managers and operational managers. These are the people who directly work on the implementation of financial technologies and managing sustainability programs and participate in the decision-making process at the institutional level.

The necessary sample size, calculated with the help of Slovin formula, made 391. Thereof, 368 complete and valid responses were obtained and included in the final analysis. Cluster sampling method was used to get regional representation. The banks were stratified into provinces (Punjab, Sindh, KPK, Balochistan, Islamabad, AJK and Gilgit Baltistan) and participants were chosen proportionally within each stratum.

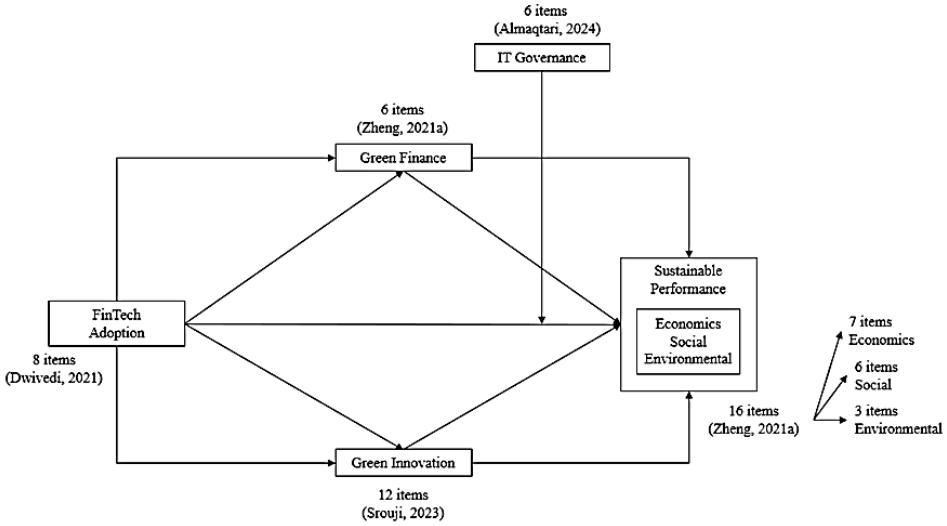
Data Proportional Representation

Province	Total Banks	Proportion (%)	Sample Size
AJ&K	507	3.13	12
Balochistan	652	4.03	16
Gilgit Baltistan	155	0.96	4
Islamabad	624	3.85	15
KPK	1921	11.87	46
Punjab	8544	52.78	206
Sindh	3783	23.38	92

The online questionnaire in Google Forms was used to collect the data. The participants were located through the official websites of respective banks and approached individually through email, LinkedIn,

and WhatsApp to ask them to participate. This was a secure way of making sure that the respondents that delivered their opinions to the study were relevant and informed. Structural Equation Modeling (SEM) was used to analyses the collected data, to check the direct, mediating and moderating effects among the study variables, and to test the theoretical model with robustness.

The study will adopt the questions related to the variables from the previous studies. FinTech will be measured by using 8 items of (Dwivedi, 2021). Green Finance will be measure by using 6 items of (Zheng, 2021). Green Innovation will be measured by using 12 items of (Srouji, 2023). Further Sustainable Performance will be measured by using 16 items of (Zheng, 2021) in which 7 item were consisted on economics performance, 6 items were consisted on Social Performance and 3 items were consisted on Environmental Performance. Lastly, IT Governance will be measured by using 6 items of (Almaqtari, 2024).



4. Results:

4.1 Confirmatory Factor Analysis (CFA)

Confirmatory Factor Analysis (CFA) is used to validate the factor structure that was identified through Exploratory Factor Analysis (EFA) and also to ensure that the observed indicators accurately measure their respective latent constructs. CFA is crucial for validity of convergent, discriminant, and model fit (Hair, F, Risher, J, Sarstedt, Marko, Ringle, et al., 2019)

4.1.1 Measurement Model Assessment

Convergent validity is assessed to determine whether the constructs of the study adequately measure the intended theoretical concepts. Internal consistency and validity of the constructs were evaluated by Factor Loadings, Cronbach's Alpha, rho_A, Composite Reliability (CR) and Average Variance Extracted (AVE). If the factor loadings are ≥ 0.50 then it is measured reliably; Cronbach's alpha value is greater than 0.70, it is said to be a good indicator of reliability; if the CR value is greater than 0.70 and AVE is greater than 0.50, it is said to have strong convergent validity (Ringle, 2019)

Convergent Validity

Items	Constructs	Loadings	Alpha	rho_A	CR	AVE
	FinTech Adoption					
FTA1	FinTech created a new opportunity for banking FinTech adoption.	0.732	0.773	0.784	0.835	0.590
FTA3	FinTech helps to innovate products and services for banks.	0.639				
FTA4	FinTech adoption is favorable in Pakistan regulations.	0.665				

FTA5	FinTech adoption process is smooth to adopt in your bank.	0.559				
FTA6	FinTech adoption required a strategic approach of technology management.	0.623				
FTA7	FinTech adoption is supported by everyone in the bank.	0.623				
FTA8	FinTech adoption creates new channels.	0.69				
	Sustainable Performance					
SPECP1	Creation of more competitive advantage.	0.659	0.938	0.940	0.946	0.523
SPECP2	Generation of more revenues.	0.683				
SPECP3	Increased contribution to govt. exchequer.	0.788				
SPECP4	Generation of additional economic benefit (economic value added).	0.798				
SPECP5	Improvement in existing assets (addition to capital).	0.828				
SPECP6	Reduction in overall risk.	0.816				
SPECP7	Saving investment and other costs.	0.786				
SPSOP8	Enhancement of the bank's image.	0.783				
SPSOP9	Establishment of trust.	0.777				
SPSOP10	Stakeholder's engagement plans.	0.791				
SPSOP11	Promotion of brand awareness.	0.829				
SPSOP12	Provision of better customers' satisfaction.	0.840				
SPSOP13	Provision of more employee benefits.	0.805				
SPEP14	Energy requirements of products and services.	0.861				
SPEP15	Energy consumption outside the organization.	0.891				
SPEP16	Reduction in carbon emissions from banking activities.	0.912				
	Green Finance					
GF1	Green financing significantly improves the revenue and market share of our bank.	0.822	0.858	0.869	0.897	0.635
GF3	Green financing significantly reduces paper usage and energy consumption in our bank.	0.79				
GF4	Green financing improves banks' compliance with environmental standards.	0.785				
GF5	Green financing improves the reputation and image of the bank.	0.789				
GF6	Green financing improves the relationship between the community and stakeholders.	0.797				
	Green Innovation					
GI1	Information disclosing the institutions' policies on environmental protection, or the institutions' worries and awareness regarding environmental protection, and/or the institutions' policies addressing climate change.	0.683	0.904	0.909	0.920	0.511
GI3	Data about the usage of technologies, such as water-saving faucets, and policies to reduce gas and water waste in internal operations at the institution.	0.723				
GI4	Data about using eco-friendly resources, such as recycled paper or solar electricity,	0.728				

	is available.					
GI5	Data on actions made to reduce staff business travel and emissions in order to mitigate climate change.	0.726				
GI6	Information on any training sessions, seminars, or workshops that will be happening soon or that are scheduled to raise public awareness of the environment.	0.696				
GI7	Any awards received by the institution in recognition of its environmentally friendly practices, contributions to environmental advances, or excellence in environmental reporting procedures.	0.694				
GI8	Data about supporting environmental sustainability initiatives, such as planting trees in cities and villages or restoring and maintaining historic buildings and infrastructure.	0.722				
GI9	Data about creating a fund to fight climate change.	0.679				
GI10	On the organization's letterhead and in other internal communication mediums, information on integrating green marketing is included, such as “Plant a Tree, Save the Environment”.	0.709				
GI11	Information on institution activities and engagement in the green movement, such as education programs for institution workers that motivate them to participate in green operations.	0.715				
GI12	The annual report has distinct pages for its green reporting.	0.781				
	IT Governance					
ITG1	Our business has an ERP system that facilitates the accessibility of data Information and data are stored in a way that can be recovered, accessed, and operated from anywhere at any point in time.	0.866	0.820	0.860	0.891	0.733
ITG2	Our business uses cloud computing to facilitate system operating.	0.786				
ITG3	Our business has a well-written and developed strategy of IT governance to deal with green finance and branchless operations that promote sustainability issues.	0.912				

Table 1 (Factor Loadings)

The analysis shows the strength of the relationship between individual items and their respective constructs in terms of the factor loadings obtained. Ringle, et al. (2019) consider factor loadings over 0.50 acceptable, and factor loadings over 0.70 as strong association with the underlying construct. Results show that most items have adequate to strong loadings and can thus be used to measure the intended constructs.

Item loadings for the FTA construct range from 0.559 to 0.732, and FTA2 is removed due to a low

loading value (less than 0.50) as it did not contribute significantly to the construct's measurement. In the same way, Green Finance (GF) and Green Innovation (GI), GF2 and GI2 were removed from the model due to low factor loadings to only keep reliable indicators.

Strong factor loadings (i.e. values ranging from 0.659 to 0.912) for the Sustainable Performance (SPEP and SPSP) construct indicate robustness of this construct. Consistent with the strong representation of the construct in the study, the Green Finance (GF) construct consistently has high loadings, ranging from 0.785 to 0.822. Also, the Green Innovation (GI) construct has acceptable loadings with values from 0.638 to 0.781, thus, the construct could be measured reliably.

Among all variables, IT Governance (ITG) construct has the highest factor loadings, from 0.786 to 0.912, which means that these indicators strongly indicate the essence of IT governance in the study.

However, factor analysis lends support to the validity of the constructs, as most of the items meet the recommended level for factor loadings. FTA2, GF2, and GI2 are removed to ensure that only the most reliable and representative items remain in the model, making the model as a whole more valid and reliable. This refinement provides a good basis for further analysis and also ensures that the finding of the study does not overfit but rather accurately reflect the relations between construct.

Results show that Sustainable Performance, Green Finance, Green Innovation, IT Governance have high reliability and validity. The Cronbach's Alpha (0.938) for Sustainable Performance means that it has an excellent internal consistency, and its CR (0.946) and AVE (0.522) also indicate adequate convergent validity. Green Finance and Green Innovation also show strong internal consistency with Alpha values of 0.858 and 0.904, and AVE values greater than 0.50, thus indicating that these constructs measure the constructs appropriately. This means that AVE (0.733) of the variance is explained by the construct's indicators, whereas IT Governance is the highest.

Although FinTech has a lower AVE (0.422) compared to the suggested threshold of 0.50, it implies that the indicators of FinTech Adoption do not provide sufficient variance in the construct. This may suggest the necessity for improved refinement of measurement items or the addition of additional items to improve construct validity. However, its Cronbach's Alpha (0.773) and CR (0.835) are still within an acceptable range, therefore the construct is still reliable.

In general, the results support that most constructs achieve the needed thresholds for convergent validity, which means that the measurement model is robust. Nevertheless, the model's validity could be enhanced by improvements in the FinTech construct.

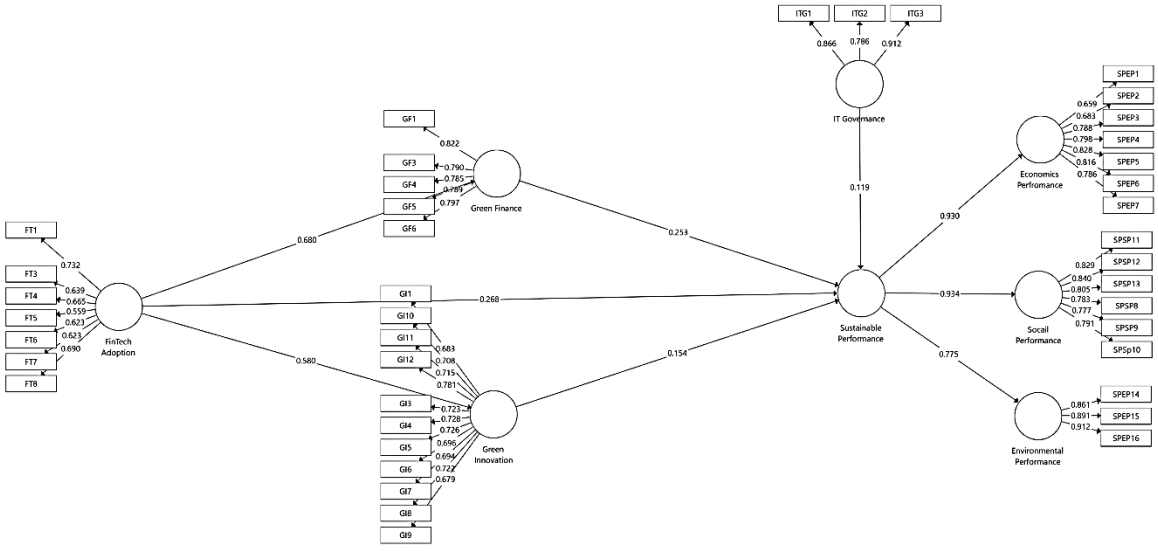


Figure 1 (Measurement Model Assessment)

4.1.2 Discriminant Validity

The discriminant validity of HTMT is more stringent measure of discriminant validity, which is the ratio of correlations between constructs. According to Henseler et al. (2015) the conservative threshold is ≤ 0.85, or ≤ 0.90 for more lenient criteria. If HTMT values are higher than these threshold values, then there is a concern of discriminant validity.

Heterotrait-Monotrait Ratio (HTMT)

	FTA	GF	GI	ITG	SP
FTA					
GF	0.803				
GI	0.653	0.751			
ITG	0.594	0.649	0.723		
SP	0.676	0.663	0.59	0.544	

Note: FTA – FinTech; GF – Green Finance; GI – Green Innovation; ITG – IT Governance; SP – Sustainable Performance.

Table 2 (Heterotrait-Monotrait Ratio (HTMT))

The HTMT value of FinTech Adoption (FTA) and Green Finance (GF) is 0.803, which is less than 0.85, implying acceptable discriminant validity. The values of HTMT of Green Finance (GF) and Green Innovation (GI) are 0.751, indicating that they are two separate constructs. The discriminant validity for the HTMT value of 0.723 for IT Governance (ITG) and Green Innovation (GI) is acceptable. The values of HTMT of Sustainable Performance (SP) and other constructs are less than 0.85, indicating that discriminant validity exists for the model.

4.2 Structure Model Assessment

The Structural Model Assessment focuses on the hypothesized relationships between constructs. SEM is used to analyze the structural model, and path coefficients, R^2 values and model fit indices are examined. R^2 value tells the variance explained by the independent variables, higher the values are, the better is the predictive power. To test the significance of path coefficients, the study uses bootstrapping techniques to test the significance of path coefficients.

4.2.1 Path coefficient

Path coefficients (β values) are the strength and direction of these relationships and significant p values ($p < 0.05$) are provided by empirical evidence to support the hypotheses (Chin & Wynne, 1998). An R^2 value of 0.26 (the first number in parentheses), 0.13 (the second), and 0.02 (the third) represent how well the independent variables predict the value of the dependent variable (Cohen, 1988).

Path Coefficients

		Standardized Estimates			Significance	Decision	Explained Variance	Collinearity
Hypotheses	Relationship	β	SD	t value	p-value	S/US	R^2	VIF
H1	FTA -> GF	0.680	0.024	28.517	0.000	S	0.462	1.000
H2	FTA -> GI	0.580	0.033	17.793	0.000	S	0.337	1.000
H3	FTA -> SP	0.280	0.044	6.316	0.000	S	0.465	
H4	GF -> SP	0.255	0.055	4.615	0.000	S		1.988
H5	GI -> SP	0.167	0.056	2.967	0.000	S		2.238

H6	FTA -> GF -> SP	0.173	0.037	4.669	0	S
H7	FTA -> GI -> SP	0.097	0.034	2.885	0.004	S
H8	FTA * ITG -> SP	0.034	0.032	1.044	0.297	US

Note: S-Supported; US-Unsupported; FTA-FinTech Adoption; SP-Sustainable Performance; GF-Green Finance; GI-Green Innovation; ITG-IT Governance

Table 3 (Path Coefficients)

The path analysis results are discussed in terms of the direct and indirect relationships between FinTech Adoption (FTA), Green Finance (GF), Green Innovation (GI), IT Governance (ITG), and Sustainable Performance (SP). Standardized path coefficients (β) denote the strength, t-values and p-values are indicators of statistical significance of the relationships.

The results indicate that FTA has a very important positive effect on GF (β = 0.68, t = 28.517, p < 0.001) and GI (β = 0.58, t = 17.793, p < 0.001) which are very significant and support the hypotheses. Additionally, FTA has a positive impact on SP (β = 0.28, t = 6.316, p < 0.001), which implies that the adoption of financial technology leads to sustainable outcomes in the banking sector. The same is true for GF (β = 0.255, t = 4.615, p < 0.001) and GI (β = 0.167, t = 2.967, p = 0.003), which positively influence SP, suggesting that the sustainable financial practices and innovation lead to the higher overall sustainability performance.

The mediation effects were also analyzed. The green finance mediating role on SP through GF is significant (β = 0.173, t = 4.669, p < 0.001), and the indirect effect of FTA on SP through GF is also large (β = 0.173, t = 4.669, p < 0.001). Also, the mediation of GI in the FTA-SP relationship is also important (β = 0.097, t = 2.885, p = 0.004), that is, innovation has a role in the translation of financial technology into sustainable outcomes. Although, the interaction effect of FinTech Adoption and IT governance on SP (β = 0.034, t = 1.044, p = 0.297) was not significant, thereby implying that IT governance does not moderate the relationship between FinTech and sustainable performance.

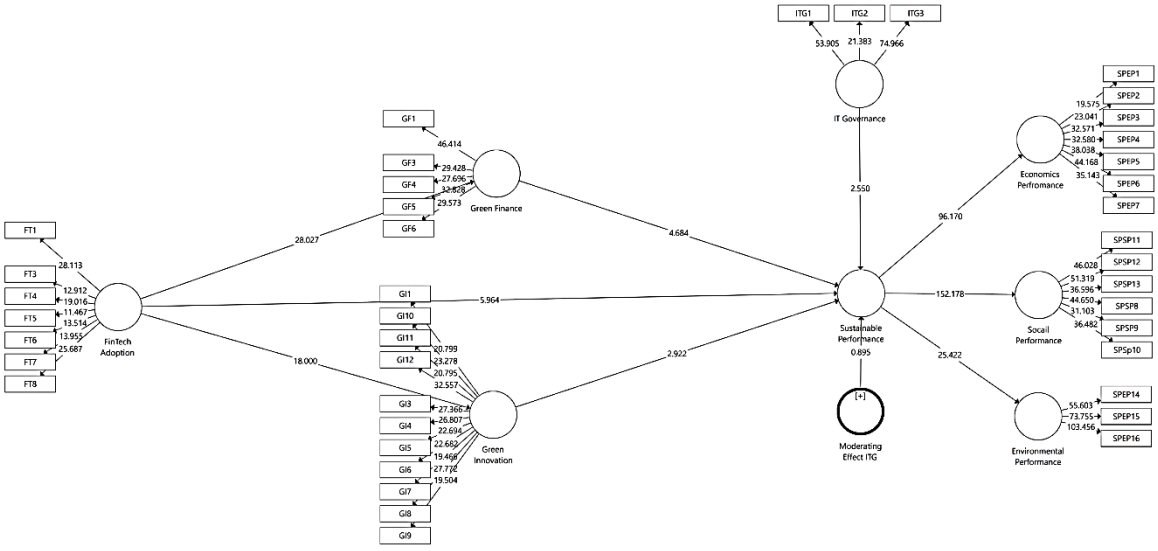


Figure 2 (Structure Model Assessment)

5. Discussion:

The objective of the research was to examine the associations amid FinTech adoption, green finance, green innovation, sustainable performance, and the moderating impact of IT governance within the Pakistani banking sector. The results indicated that there were strong positive correlations among the important variables: FinTech adoption was correlated with green finance (β = 0.68, p = 0.000), green innovation (β = 0.58, p = 0.000), and sustainable performance (β = 0.28, p = 0.000).

Moreover, green finance (β = 0.255, p = 0.000) and green innovation (β = 0.167, p = 0.003) were identified to benefit sustainable performance directly. The hypothesis that green finance (β = 0.173, p = 0.000) and green innovation (β = 0.097, p = 0.004) mediate significantly the relationship between FinTech adoption and sustainable performance was supported, thus showing that FinTech adoption positively affects sustainability more when assisted by the instruments of green finance and green innovation strategy.

Nevertheless, the moderation test revealed that IT governance was not a significant moderator between the FinTech adoption and sustainable performance (β = 0.034, p = 0.297), so the associated hypothesis was rejected. This has the implication that, although IT governance plays an essential role in ensuring operational compliance and risk management, it is yet to be strategically aligned with sustainability initiatives within the Pakistani banking environment. Similar by Al-Sartawi et al., (2020), Weill and Ross (2004), and Mikalef et al., (2020), previous researchers also suggest that the contribution of IT governance to improved sustainability performance may be hindered by rigid IT frameworks or immature governance structures in newer economies.

Also, the research established that the effect of green finance on sustainable performance was more significant than that of green innovation, yet both were statistically significant. These findings imply that FinTech involvement combined with the sustainability-oriented practices, specifically, green finance and green innovation, can be transformative in terms of improving the long-term performance of banks, and the absence of the moderating influence of IT governance indicates the necessity of its strategic reorientation toward facilitating environmental objectives. In general, the paper touches upon the significance of digital financial instruments, innovation, and green investment in the sustainability of banking, and it also reveals the situational weakness of the governance instruments in developing nations such as Pakistan.

6. Conclusion:

Through a valuable insight has been developed through this study, on the dynamics among FinTech adoption, green finance, green innovation, and sustainable performance in the Pakistani banking sector. The findings established that the use of FinTech has a considerable contribution to the sustainable performance both directly and indirectly via its beneficial impact on green finance and green innovation. These intermediaries reinforce the linkage between the digital financial practices and environmental, economic and social sustainability performances. Although FinTech, green finance, and green innovation are strategic resources, that help banks to improve sustainable performance the study found no significant effects of IT governance moderating the relationship between FinTech and sustainability. This observation indicates that although the governance frameworks are vital to ensure compliance and operational stability, they do not necessarily facilitate innovation and sustainability in emerging economies whose digital infrastructures and policy alignment are yet to be developed. This study contributes to the literature theoretically by including the mediators and challenging the universality of the IT governance effectiveness in sustainability. Empirically, it provides strong statistical results based on a sample of Pakistan through SEM analysis, and practically, it gives some policy recommendations that regulators and banking organizations could follow to boost their digital and green transformation efforts. Although there are certain drawbacks related to the cross-sectional nature of the study and its focus on the sector, the study provides avenues of future research on the sub-dimension of governance, long-term effects, and the application of FinTech in other areas of the financial segment. Finally, this study highlights the increased role of combining technologies and sustainability, and it requires more robust institutional settings, digital infrastructure, and strategic alignment to optimize the sustainable opportunities of financial technologies in banking.

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