Innovations

The Impact of Fintech Innovation on Green Growth in Saudi Arabia: Does Green Finance Matter?

Kamel Bel Hadj Miled[1,2]
[1]University of Shaqra, College of Science and Humanities,
Dawadmi, Saudi Arabia
[2]University of Sousse, Higher Institute of Management,
Sousse, Tunisia

Abstract: *This study analyzes the effects of fintech innovation and green finance on green growth in Saudi Arabia from 2000 to 2022, using the ARDL bounds testing approach. We identified several significant findings for both the short-term and long-term from the ARDL bounds testing methodology.Fintech and green finance play a pivotal role in driving sustainable economic growth in Saudi Arabia. This underscores the crucial role of technological progress in fostering sustainable economic practices. Recent Research indicates that fintech innovation primarily supports green economic development through mechanisms such as green credit and green investment. As a result, advancing fintech innovation can significantly enhance the progress of green finance, offering valuable insights for countries worldwide.*

Keywords*: Green finance; Fintech; Green finance; Green Growth*

1-Introduction

Fintech innovation represents a significant shift in the financial sector, driven by technological advancements that enhance efficiency and accessibility of services. The term "fintech" includes a wide range of tech-driven solutions aimed at improving, automating, and transforming financial operations. Innovations such as digital payment systems, blockchain technologies, peer-to-peer lending platforms, and robo-advisors illustrate this evolution. The global financial crisis of 2008 served as a catalyst for fintech growth, challenging traditional banking models and encouraging disruptive technologies to reshape consumer expectations regarding financial offerings (Y.W.Alquliti, 2022).

In Saudi Arabia, fintech is integral to the Kingdom's Vision 2030, which seeks to diversify the economy by fostering technological advancement and entrepreneurship within finance. According to G.Zhou et al. (2022),thefintech extends beyond enhancing conventional finance; it also promotes sustainable economic practices. The intersection of fintech with green finance presents

unique opportunities to stimulate green growth through innovative financing mechanisms supporting eco-friendly initiatives. The integration of fintech across various sectors reflects global trends prioritizing sustainability. Fintech applications can facilitate the issuance of green bonds and serve crowdfunding platforms for renewable energy projects, thereby reducing funding barriers for environmentally-focused efforts (Nenavath& Mishra, 2023). Furthermore, advancements like blockchain technology enhance transparency and traceability in green financing while optimizing supply chain processes linked to sustainability initiatives.

Despite its potential to drive economic growth through innovation and accessibility, there is an urgent need for more in-depth exploration of fintech's specific impacts on green growth dynamics. Much current literature primarily focuses on traditional economic metrics without sufficiently examining how fintech influences environmental outcomes (Aziz et al., 2024). Developing comprehensive evaluative frameworks that assess both fintech's impact on economic indicators and its role in facilitating green investments will provide stakeholders with valuable insights into this complex relationship.

In summary, while interest is growing in the synergy between fintech innovation and green growth—especially regarding the catalyzation of renewable energy investments—the investigation of this intersection is still evolving.Hence, scholars are directing their attention towards diverse factors, including green finance (GFN) and financial technologies (fintech), in order to discover means of establishing a sustainable and eco-friendly global environment (M.C. Udeagha, E. , 2023).

Green finance refers to financial products and services that support environmentally sustainable and socially responsible practices. The goal of green finance is to promote investments and projects that have positive environmental impacts while also providing financial returns. This concept has gained prominence as a response to global environmental challenges, such as climate change, pollution, and resource depletion.

Each development country has its own FinTech ecosystem, regulatory framework, and level of adoption. FinTech companies in these countries often benefit from access to a sophisticated financial market, a large consumer base, and a supportive regulatory environment. They play a crucial role in advancing sustainable finance by facilitating the development of platforms for green investments, impact investing, and other environmentally conscious financial products. This can contribute to better-informed decision-making for both investors and financial institutions.The integration of FinTech and green growth aligns with the broader concept of sustainable finance, where financial services are directed towards environmentally and socially responsible activities. It's important for regulators, financial institutions, and FinTech innovators to collaborate to create a supportive ecosystem for these initiatives and ensure that

financial technology contributes positively to environmental sustainability and green economic development.

Green growth represents a paradigm that promotes economic development while ensuring sustainable use of natural resources and minimizing environmental impacts. Its significance lies in the ability to decouple economic advancement from environmental harm, paving the way for a sustainable future. This concept has gained popularity globally, particularly as a response to climate change and the urgent need for ecological preservation. According toAbro et al., (2023), Saudi Arabia has set an ambitious goal of achieving carbon neutrality by 2060, necessitating a holistic approach to integrate green growth into national economic planning.

At its essence, green growth is based on sustainable development principles, which stress meeting current needs without compromising future generations' abilities to meet theirs. Within this framework, green growth includes various strategies aimed at enhancing productivity while reducing resource consumption and pollution levels. For example, adopting cleaner technologies and sustainable practices in energy, agriculture, and transportation can significantly lower carbon emissions, foster job creation, and diversify the economy.

The role of green finance is crucial in facilitating the transition towards green growth. Green finance refers to investments directed toward projects that yield environmental benefits, thereby supporting sustainability goals. Tamasigaand al., (2022) proposed thatfintech innovations can play a vital role in mobilizing resources for these investments by providing platforms for efficient capital allocation to renewable energy initiatives and sustainable infrastructure projects. Financial technologies enable instruments like crowdfunding and green bonds, democratizing access to funding for environmentally focused ventures.

Integrating principles from Islamic finance into green finance frameworks may enhance adherence to sustainability ideals. Another research, argued that Islamic finance aligns closely with green finance, especially regarding ethical investment practices that prioritize socio-environmental welfare alongside profit generation. This synergy could facilitate greater investment flows into sustainable projects across the Kingdom.

Green finance is essential for promoting economic growth by directing financial resources toward environmentally sustainable projects. Its integration into the financial sector not only ensures effective capital allocation but also addresses critical issues like climate change and environmental degradation. The progression of green finance showcases its diverse roles, including risk management, encouraging sustainable investments, and fostering accountability in financial operations. By employing various financial instruments such as green bonds and eco-loans, this sector can mobilize significant capital for initiatives aligned with sustainable development goals (SDGs).

In Saudi Arabia, commitment to green finance is demonstrated through initiatives like the 'PIF[1] Green Finance Framework,' which aligns national policies with global sustainability targets. This approach reflects an increasing recognition that economic growth must coexist with responsible environmental practices (M.O. Alhejaili., 2024). Promoting green finance not only enhances investments in clean technologies but also supports long-term economic diversification efforts outlined in Vision 2030.

Financial institutions play a crucial role in advancing green finance through their lending practices. By integrating environmental criteria into evaluations and investment strategies, banks can encourage businesses to adopt more sustainable practices while managing their exposure to climate-related risks. This alignment can strengthen financial stability by reducing vulnerability to sectors affected by environmental regulations or shifts toward sustainability.

Furthermore, green finance significantly contributes to job creation and innovation within sustainability-oriented sectors. Investments in renewable energy, for instance, not only combat climate change but also generate employment across various industries. This connection between job creation and environmental responsibility underscores the importance of merging economic progress with ecological considerations.

The interplay between fintech innovations and green finance introduces additional potential for boosting economic growth in Saudi Arabia. By leveraging advanced technologies like big data analytics, artificial intelligence, and blockchain, fintech can optimize resource allocation for greener projects while lowering transaction costs associated with traditional financing methods (Zhou et al., 2022). Such efficiencies enhance the capability of financial institutions to support environmentally friendly investments.

2-Literature review

The concept of green growth involves fostering technological innovations and sustainable industries by generating job opportunities, alleviating poverty, promoting social accountability, and enhancing environmental outcomes through the delivery of clean water and energy resources. Morssy's (2012) research carried out in Austria emphasizes the importance of achieving a balanced relationship between consumer needs and the conservation of natural resources by leveraging advanced technology.

Qian and al. (2021) have highlighted the substantial contribution that intelligent cities can make to the development of Green growth in China.Furthermore, a rise in GRW would directly enhance the generation of renewable energy and diminish reliance on fossil fuels. These two factors would contribute to a decrease in emission levels and enhance the overall environmental sustainability of an

[1]Public Investment Fund

economy(He et al., 2019). In addition to the unpredictable changes in climate that pose significant obstacles to green growth, the connection between the environment and the economy is also a topic of discussion. According to a study by Kazzi (2014) in Arab countries, the integration of economy and environment is crucial for achieving overall growth by promoting job creation, social equity, and the sustainable use of natural resources. This highlights the advantages of implementing a green growth strategy in Arab nations.

2.1 Dynamic connectedness of Fintech, green financeandGreen Economic Growth

An increasing body of research has focused on the relationship between fintech innovations and green finance, recognizing their potential to support sustainable economic development (Zhou and al., 2021). Highlight the limited literature directly exploring this intersection. Their study demonstrates that fintech innovation significantly promotes green growth through mechanisms like green credit and investment. Analyzing provincial panel data from China from 2011 to 2018, they show how fintech serves as a catalyst for advancing green finance, with varying impacts across different regions

In African nations, Tamasigaand al. (2022) conduct a systematic bibliometric analysis to examine how fintech can facilitate a transition to a greener economy. Their findings indicate growing scholarly interest in green fintech and its potential to drive sustainable economic growth amidst climate change challenges. They propose an integrated framework emphasizing opportunities for deploying green fintech across sectors to enhance environmental sustainability along with economic goals.

Aziz and al. (2024) further explores the links between fintech innovation and energy transition in China. Their research identifies pathways through which fintech influences green growth while highlighting the need for empirical evidence in this area. They provide insights into how energy transitions can strengthen this relationship, contributing valuable theoretical frameworks for future research.

M.O. Alhejaili, (2024), examines Saudi Arabia's regulatory framework, offering perspectives on integrating climate risk considerations with sustainability goals in financial regulations. This research outlines strategies for enhancing green finance initiatives tailored to regional contexts while aligning them with broader global sustainability aspirations

He and his collaborators address the dual nature of fintech as both a promoter of sustainable practices and a source of challenges related to energy consumption from digital infrastructures. They argue that while fintech facilitates funding for environmental projects, such as renewable energy initiatives or carbon credit systems, it is crucial to consider the potential environmental costs associated with increased resource utilization (He et al., 2024).

Nenavath& Mishra, (2023) provides empirical evidence of the relationship between green finance, fintech, and sustainable economic growth in India through an eleven-year panel data analysis across various states. Their findings underscore the significant contributions of both sectors in refining financial structures and enhancing environmental quality through strategic policy recommendations aimed at solidifying their integration.

Fintech's role becomes particularly significant when considering its ability to streamline operations in green financing, fostering effective collaborations between institutional investors and public entities involved in sustainability projects. Utilizing technologies such as blockchain for transparency and AI-driven analytics for enhanced decision-making in financing models, fintech strengthens traditional funding methods.

In conclusion, as evolving trends continue to reshape the global financial landscape toward greater sustainability objectives, regions like Saudi Arabia are positioned at the forefront of this transformation.

Based on this research, this study proposes the following hypothesis:

H1: Fintech innovation plays a crucial role in driving sustainable growth

H2: Fintech innovation has a positive impact on green growth by increasing green credit andthe level of green investment

The existing literature captures a rapidly evolving field dedicated to understanding how fintech can effectively bolster global green finance initiatives, providing essential insights into strategies for advancing sustainable development.Green finance not only provides a pathway to sustainable economic growth but also supplies the critical resources needed to navigate toward an ecologically viable future.

2.2 Impact of Green Finance onGreen Economic Growth

Green finance has emerged as a vital driver for economic development, particularly within the framework of sustainable growth. It plays a crucial role in reshaping financial systems, optimizing resource distribution, and enhancing environmental responsibility. By integrating ecological factors into financial decision-making, green finance offers a unique avenue for achieving both sustainable and equitable economic progress. Recent studies indicate that green finance stimulates investment in environmentally friendly initiatives while promoting broader economic efficiencies, ultimately boosting productivity.

In Saudi Arabia, there is an increasing recognition of green finance that aligns with the Vision 2030 initiative, aimed at diversifying the economy and reducing dependence on oil revenues. By channeling investments into renewable energy projects and sustainable practices, green finance not only catalyzes economic activities but also addresses pressing environmental issues. This approach can lead to job creation in emerging sectors focused on sustainability and innovation, which are essential for lasting economic resilience.

Moreover, fintech innovations significantly enhance the impact of green finance on economic growth. These solutions facilitate greater access to capital for green projects by improving transaction efficiency, expanding investor engagement through crowdfunding, and providing more precise risk assessments via data analytics (G.Zhouand al., 2022). Such advancements lower barriers for small and medium-sized enterprises (SMEs) eager to adopt sustainable practices, enabling these businesses to contribute meaningfully to local economies while committing to environmentally responsible operations.

The positive correlation between green finance and improved economic outcomes is reinforced by evidence showing that well-structured financing mechanisms support environmental projects while simultaneously enhancing overall financial efficiency. Prioritizing investments that yield both ecological benefits and economic returns allows countries to boost their GDP while reducing carbon emissions.

Despite existing challenges related to regulatory frameworks and market readiness for widespread adoption of green finance practices, empirical findings suggest that proactive policies can drive significant advancements. Financial institutions are increasingly embedding environmental criteria into their lending practices, promoting investments aligned with sustainable development goals (SDGs) (Tidjani.C&Madouri.A, 2024).

The convergence of fintech and green growth in Saudi Arabia represents an emerging area of study, yet significant gaps persist. Existing literature primarily focuses on developed markets, leaving a notable lack of understanding regarding these concepts within Saudi Arabia's unique socio-economic context. (M.O. Alhejaili, 2024) indicates that much of the current work overlooks the distinct challenges and regulatory frameworks inherent to Saudi Arabia’s financial landscape, particularly under initiatives like Vision 2030.

Many studies have proposed methods for integrating green finance into global financial systems. However, there is a deficiency in empirical analyses tailored to the cultural and operational realities of Saudi Arabia. Customization of these structures is crucial, as it could significantly enhance the effectiveness of green finance initiatives aimed at promoting sustainable economic development.

Another critical gap involves understanding the role of fintech innovations in expanding access to green financing for startups and small businesses in Saudi Arabia. The existing literature inadequately explores how fintech can bridge funding disparities for environmentally friendly projects, especially given the reluctance of traditional funding sources to invest due to perceived risks associated with ecological initiatives. For instance, (Y.J.Amuda&R.A.Alamri., 2024) discusses challenges linked to market constraints and investor awareness concerning the benefits of sustainable finance. This highlights the urgent need for targeted research into how fintech solutions can stimulate investments in eco-conscious projects.

Additionally, there is a conspicuous lack of comparative studies assessing the impact of fintech on green growth across different regions within Saudi Arabia or in relation to other countries undergoing similar economic transitions. As suggested by Aziz and al., (2024) expanding research beyond isolated case studies could provide valuable insights into overall trends and best practices for merging fintech with sustainability efforts.

3. Construction of green growth index

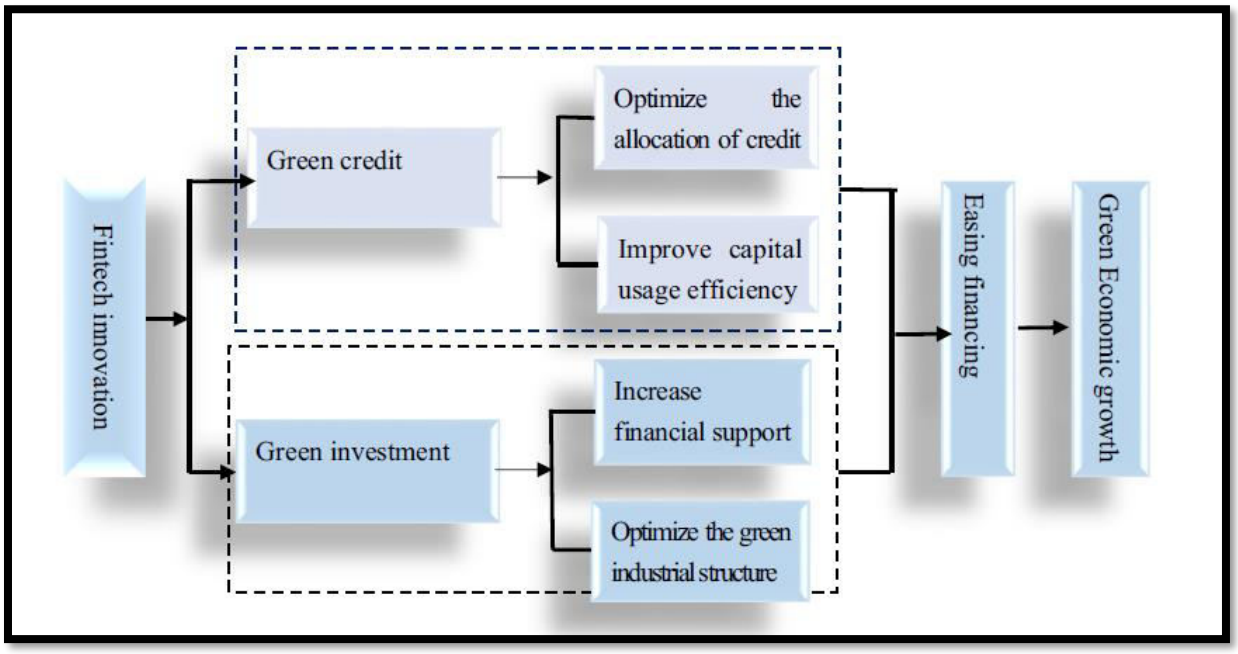
The construction of a Green Growth Index involves the development of a composite indicator that assesses the progress of countries or regions in achieving sustainable and environmentally friendly economic growth. The majority of early studies on green growth and sustainable development relied on a single indicator, which limited their ability to provide a comprehensive evaluation of green growth (Fehr and al., 2004; Huge et al., 2010; Ou, 2012). Subsequently, some researchers utilized multiple indicators to develop a green growth index.

According to Jacobs (2012), Song and al. (2019), Hickel and Kallis (2020), Li and Liao (2020), and Yunqian, Mo (2023), the key factors determinants of green growth are green investment, financial markets and institutions, internet usage, and research and development.

To support the empirical analysis of the impact of financial technology innovation on green growth, this study begins by exploring the concept of green growth, selects multiple indicators, and establishes a three-tier index system to assess the level of green growth.

This paper draws on the research ofYunqian Mo et al., (2023); Guangyou Zhou (2022) and Yi Li et al (2024), we constructs the green growth index from fiveaspects:green finance (GFN), financial technology (FINTECH), education %(EDC), urban unemployment rate (Labor) and research and development (RD).

Fig. 1. The impact mechanism of fintech innovation on green growth.



Source: Guangyou Zhou et al (2022)

Fig. 1 represents the interplay between fintech innovation, financial mechanisms, and their impact on green economic growth. Fintech Innovation acts as the central driver, influencing two key areas: Green Credit and Green Investment with Increasing financial support and optimizes the green industrial structure. Both green credit and green investment contribute to easing financing, which facilitates green economic growth.

4. Methodology

4.1. Variable selection

This study utilizes the green growth index (GG_t) acts as the primary dependent variable, representing sustainable economic performance, using quarterly time series data for the period from 2000 to 2022;

- FNTECH as the primary explanatory variables,is represented by "Number of Internet users", "Domestic credit to banksector", and "Mobile phone subscriber data" were used for developing of financial technology.Theindicator was developed through the application of Principal Component Analysis(PCA).
- Greenfinance (GFN), representing by green investment measure by Total nuclear, renewables, and other production (quad Btu).
- Education %(EDC), is the students enrolled in regular higher education institutions to the overall population
- The registered urban unemployment rate (Labor): A lower labor input in the region hinders the enhancement of its green growth level
- Research and development (RD)are included to account for additional factors affecting green growth.

Table 1. **Variable definition and sources**			
Variable	Symbol	Definitions	Source
Green growth	GG	Environmentally adjusted multifactor productivity	OECD
Green finance	GFN	Green investmentmeasure by Total nuclear, renewables, and other production (quad Btu)	World Bank
Financial technology	FNTECH	- Number of Internet users - Domestic credit to bank sector - Mobile phone subscriber	World Bank
Education	EDC	students enrolled in regular higher education institutions to the overall population	World Bank
Research and development	RD	Research and development expenditure (% of GDP)	World bank
Registered urban unemployment rate	Labor	urban unemployment rate	World bank
OECD:**Organisation for Economic Co-operation and Development**			

4.2. Econometric techniques

In exploring the impact of on green growth, the Autoregressive Distributed Lag (ARDL) employed to analyze the relationship between various economic and environmental indicators.

We construct an empirical model grounded in a standard production function that assumes constant returns. The overall output function, as a function of time (t), can be represented as follows:

$$Y_{(t)} = \alpha_0 + \beta X_{(t)} + \varepsilon_{(t)} \quad (1)$$

Incorporating our variables, the econometric framework can be expressed as follows:

$GG_t = \alpha_0 + \beta_1 FINTECHt + \beta_2 GFNt + \beta_3 EDC_t + \beta_4 RDP_t + \beta_4 Labor_t + \varepsilon t$ (2)

The examination of intermediate variables will be conducted to evaluate hypotheses H1 and H2, which propose that fintech innovation positively influences green growth by enhancing green credit and green investment.

The aim of this analysis is to examines both the short- and long-term effects. For this purpose, we employ the ARDL approach developed by Pesaranand al. (2001). The ARDL is typically represented as equation (3) in the following format:

$$DGG_t = \alpha_0 + \sum_{i=1}^{n} \beta_1 DGG_{t-i} + \sum_{i=1}^{n} \beta_2 DFINTECH_{t-i} + \sum_{i=1}^{n} \beta_3 DGFN_{t-i} + \sum_{i=1}^{n} \beta_4 DEDC_{t-i} + \sum_{i=1}^{n} \beta_5 DRDP_{t-i} + \sum_{i=1}^{n} \beta_6 DLabor_{t-i} + \alpha_1 GG_{t-1} + \alpha_2 FINTECH_{t-1} + \alpha_3 GFN_{t-1} + \alpha_4 EDC_{t-1} + \alpha_5 RDP_{t-1} + \alpha_6 Labor_{t-1} + \lambda \mathrm{ECM}_{t-1} + \varepsilon_i \quad (3)$$

Where D denotes the first difference operator; n represents the optimal lag length; α_0 represents the intercept; β_1 , β_2, β_3, β_4 , β_5 , β_6 denotes short-run coefficients; and α_1, α_2, α_3, α_4, … are coefficient for long run.The error correction term (ECM) represents the long-run equilibrium relationship between the variables, that indicates the valid long-run relationship if the estimates of λ are negatively significant.

The ECM incorporates an error correction term (ECT), which measures the extent of deviation from the long-term equilibrium in one time period and adjusts the dependent variable in subsequent periods to restore equilibrium. This allows the model to capture both short-term effects and the speed of adjustment toward the long-run equilibrium.The Autoregressive Distributed Lag (ARDL) model offers several advantages in econometric analysis, particularly when analyzing relationships between variables with different levels of integration (I(0) and I(1)and a blend of both.

Before applying the ARDL model, it is recommended to assess the stationarity of the data. This research employs the Augmented Dickey–Fuller (ADF) and Phillips-Perron (PP) unit root tests to address stationarity concerns. Additionally, the bounds test for cointegration was conducted independently for all four models under investigation to validate the cointegration analysis. The null hypothesis in the bounds test asserts that no cointegration exists among the variables. To reject this hypothesis, the F-statistic must exceed the upper bound critical value.Moreover,the study analyzes time series data, prompting the implementation of several diagnostic tests associated with heteroscedasticity, serial correlation, and the overall model fit

4. Results and Discussion

4.1Tests for unit root

The study employed panel unit root tests, including the IPS test (Im et al., 2003). The null hypothesis of this test is the existence of a unit root in the data. According to the results, most variables exhibit stationarity at the first difference, as confirmed by both the ADF and PP unit root tests (see Table 2).

Table 2: Panel unit root tests

Im, Pesaran and Shin (IPS, 2003)		
Variables	Trend and intercept Level	First Difference
GG	0.975	–2.979**
FINTECH	-0,165	-2.117***
GFN	0.322	-5.60***
FNTECH	1.206	-3.23***
EDC	0.184	-3.154***
RDP	-0,163	-5.641
Labor	0.206	-4.23***

Note: *** p<0.01; ** p<0.05; and * p<0.1

Source: Authorowncalculations.

4:2. Test for panel cointegration

The subsequent step focuses on analyzing panel cointegration through the error correction model (ECM) proposed by Westerlund (2007). Furthermore, the Kao residual cointegration test, developed by Kao et al. (1999), was applied to confirm the existence of long-term relationships among the variables.

Table 3: Westerlund (2007) Panel cointegration Test.

Variables	**Model**	**P-Value**
GG	-11.835***	0.000
FINTECH	-9.305***	0.000
GFN	-10.396***	0.000
FNTECH	-9,25***	0.000
EDC	-8.25***	0.000
RDP	11.41***	0.000
Labor	12.11***	0.000

Note:Note: *** p<0.01; ** p<0.05; and * p<0.1

Source: Authorowncalculations

4:3: ARDL estimates of green growth

The interplay between technological advancement, financial practices, education, and greeneconomic variables has garnered significant attention in economic research. Particularly, the emergence of financial technologies and green finance represents a shift in how financial resources can drive green development. Given the complexities of these relationships, the ARDL model allows for the examination of both short and long-term relationships among variousvariablesas shown in Table4. The high R-squared and adjusted R-squared values (0.989 and 0.987 respectively) indicate that the model explains a substantial proportion of the variation in the dependent variable. The highly significant F-statistic further confirms the overall model's validity.

The estimation results from the ARDL estimation in table4, Reveala significant positive relationship between fintech innovation and green growth both in the short and long run. This underscores the crucial role of technological progress in fostering sustainable economic practices. The connection between fintech innovation and economic indicators is crucial forfostering green growth, particularly in Saudi Arabia. Fintech, or financial technology, utilizes advanced technologies to improve efficiency and accessibility in the financial sector. Its evolution has led to significant changes in the delivery of financial services, enhancing the overall economic landscape.

Numerous studies indicate that fintech innovation positively influences various economic indicators, including investment levels, productivity rates, and employment statistics.

A key aspect of this relationship is fintech's capacity to streamline capital allocation towards environmentally friendly initiatives. By leveraging technologies such as big data analytics and blockchain, fintech enhances risk assessment and credit scoring for businesses committed to sustainable practices. This optimization allows both traditional banks and emerging financial institutions to direct funding into green projectsranging from renewable energy to sustainable agriculture reinforcing investor confidence and stabilizing markets.

Fintech's impact extends beyond mere transaction facilitation; it actively reduces information asymmetries in the credit market. According to Zhou and al., (2021), the improved access to information can ease financial frictions that hinder investments in eco-friendly projects. When businesses effectively demonstrate their green credentials through advanced fintech platforms, they are more likely to secure essential funding, thereby driving economic activities aligned with sustainability goals. This relationship, suggesting that enhanced financial technologies facilitate increased funding for environmentally sustainable projects, thereby promoting green growth. Ultimately, the interplay between fintech innovation and key economic indicators illuminates a pathway toward achieving green growth aspirations in Saudi Arabia. By effectively leveraging technology-driven financial services aligned with sustainability objectives, the nation can navigate its economic development while prioritizing ecological

preservationa paradigm increasingly relevant on a global scale as nations strive toward climate targets

Furthermore, the short and long run results show that green finance significantly and positively affects Saudi's green growth. The coefficient of (1.073), coupled with a t-statistic of (2.856), points to a robust positive relationship. Green finance's role in promoting sustainable investments yields immediate economic benefits.

The examination of how green finance provides significant insights into these interactions in green growth in Saudi Arabia. Empirical findings indicate that green finance significantly advance green growth and improve access to green investment, essential for sustainable economic development. This aligns with previous studies, such as those by Wang and al. (2021),

Table 4: Results of ARDL

Indep. Variables	Coefficients	T-Statistic
Short-Run Model		
DInFINTECH	0.035**	3.274
DInGFN	1.073**	2.856
DInEDC	0.002**	3.007
DInRD	0.003***	2.626
DInLABOR	0.170**	3.005
Long-run		
InFINTECH	0.015**	1.790
InGFN	0.716***	8.712
InEDC	2.784***	4.780
InRD	0.743	3.580
InLABOR	0.201**	2.231
C	11,005	7.448
R-squared	0.989	
Adjusted R-squared	0.987	
F-statistic	389.919	
Prob (F-statistic)	0.000	
Note: *.**,*** is for the significance level of 10%;5% and 1%		

which highlight how fintech can alleviate financial constraints leading to reduced carbon emissions in production processes and ultimately fostering green growth.

Shen and al. (2021) reinforce our conclusions, asserting that green investments play a crucial role in improving the efficiency of climate markets and energy systems, which in turn significantly drive green growth.
Another study supports our findings by arguing that green finance can have an intermediary role between fintech innovation and green growth. Indeed, the significant mediation of green finance is developed with many channels, including equity finance, bond finance, venture capital, crowdfunding, and internet finance, increasingly integrating with fintech innovation. in complex dynamic global economies, fintech innovation can improve green finance by reducing the risk of real options of low-carbon technology, reducing information asymmetry, and providing a lower-cost capital asset pricing system to integrate data, reduce the credit risk of green firms, and reduce the capital cost of green technology innovation.Our findings align with Mahat and al. (2019), who argue that the growth of financial institutions supports green growth by enabling industries to adopt advanced, eco-friendly machinery. The development of financial institutions also facilitates access to affordable short-term financing for investors, which is essential for accelerating green growth initiatives. While, Research and development (RD) have a significative and positive effect on green growth in Saudi Arabia. This result is consistent with Lin and Benjamin (2017), who observed that advancements in R&D significantly contribute to promoting green growth.
In short and long run impact of education is significant and positive on green growth. the level of education plays a crucial role in driving green growth by fostering awareness, innovation, and the adoption of sustainable practices. A well-educated population is better equipped to develop and implement eco-friendly technologies, promote environmental conservation, and support policies aimed at achieving sustainable development. Other research indicates that public spending on human resource development and green energy technology R&D fosters the growth of a green economy by supporting (labor)and technology-driven production activities. However, the impact varies across countries (Zhang and al., 2021a, 2021b).

5. Conclusion and implications

This paper attempts to examine the impact of fintech innovations on green growth and green finance in Saudi Arabia using the Autoregressive Distributed Lag method from 2000 to 2022. In order to avoid omitted variable bias, achieve more accurate results, and minimize endogeneity problems, some relevant variables are added after testing and verifying the stationarity properties of the data. The empirical results demonstrate that, first, a long-run positive relationship is established between fintech innovations and green growth in Saudi Arabia. Second, it indicates that fintech innovations drive green growth through the increasing supply of green finance, opening the credit mechanism of green finance. Third, (RD) (EDC) and the unemployment rate, assets positively influence

green growth, while barriers to international business include salary, deposit rate, and opportunities for small and medium enterprises.

The findings emerging from this empirical study can be utilized to plan a strategy to foster green growth in Saudi Arabia through the mediating effect of developing a more systematic program towards the promotion of green finance to enhance green growth. Moreover, for policymakers, by affecting the credit mechanism of green finance through relevant policies, it is possible to develop new types of green innovative finance mechanisms and construct innovative public-private partnerships for investment funds in green projects. Entrepreneurs in green businesses are inspired towards innovation. Additionally, policymakers can establish legislation to promote environmental protection, which would enhance the advancement of green innovative private sectors in Saudi Arabia. Furthermore, it is possible to promote local culture to increase the level of understanding of the green industry and enhance competitiveness in the international market, specifically supporting SMEs in this field.

Aligning with Saudi Arabia's Vision 2030, which emphasizes digital transformation, initiatives should be introduced that offer grants and incentives to startups focused on green finance technologies. Establishing regulatory sandboxes can also promote experimentation with innovative financial products aimed at increasing transparency and accessibility in this sector (M.O. Alhejaili, 2024). By fostering an environment conducive to innovation, policymakers can position fintech as a key partner in sustainable financing.

Addressing regional disparities through tailored strategies will enhance the effectiveness of green finance initiatives across Saudi Arabia. Regional pilot zones could act as testing grounds for innovative financial practices, allowing successful strategies to be shared nationwide. By leveraging local conditions and involving stakeholders, these regions can accelerate the adoption of green finance across multiple sectors.

In summary, the responsibilities of policymakers and stakeholders revolve around creating a conducive regulatory environment, promoting technological advancements, integrating societal values into financial practices, enhancing cooperation among financial institutions, and fostering regional development of green finance initiatives. These measures are crucial not only for achieving sustainability goals but also for ensuring that Saudi Arabia stays competitive in the evolving landscape of global finance

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Funding

There is no outsider funding.

References:

1. *Al Hammadi, T., Nobanee, H., (2019?.FinTech and sustainability: a mini-review. SSRN Electron. J.*
2. *Al Mamun, M., Boubaker, S., Nguyen, D.K., (2022). Green finance and decarbonization: evidence from around the world. Finance Res. Lett. 46, 102807*
3. *Asif Ali Abro, NaushadAlam, MuntasirMurshed, Haider Mahmood, Mohammed Musah, A. K. M. Atiqur Rahman. (2023). Drivers of green growth in the Kingdom of Saudi Arabia: can financial development promote environmentally sustainable economic growth?.link.springer.com.*
4. *Bakry W, Mallik G, Nghiem X-H, Sinha A, Vo XV (2023) Is green finance really "green"? Examining the long-run relationship between green finance, renewable energy and environmental performance in developing countries. Renew Energy 208:341–355*
5. *Bo He, Wen Jie, Haihong He, MajedAlsubih, GioiaArnone, SamariddinMakhmudov. (2024). From resources to resilience: How green innovation, fintech and natural resources shape sustainability in OECD countries. www.sciencedirect.com.*
6. *Chudik A, Pesaran MH (2015). Common correlated effects estimation of heterogeneous dynamic panel data models with weakly exogenous regressors. J Econom. 188(2):393–420.*
7. *Fehr, M., Sousa, K.A., Pereira, A.F.N., Pelizer, L.C., (2004). Proposal of indicators to assess urban sustainability in Brazil. Environ. Dev. Sustain. 6, 355–366.*
8. *Ghazala Aziz, SulemanSarwar, RidaWaheed, Humaira Anwar, Mohd Saeed Khan. (2024). Relevance of fintech and energy transition to green growth: Empirical evidence from China.www.sciencedirect.com.*
9. *Guangyou Zhou, Jieyu Zhu, SumeiLuo. (2021). The impact of fintech innovation on green growth in China: Mediating effect of green finance. www.researchgate.net.*
10. *Guangyou Zhou, Jieyu Zhu, SumeiLuo. (2022). The impact of fintech innovation on green growth in China: Mediating effect of green finance. www.sciencedirect.com.*
11. *He, L., Liu, R., Zhong, Z., Wang, D., Xia, Y., 2019. Can green financial development promote renewable energy investment efficiency? A consideration of bank credit. Renew. Energy 143, 974–984.*
12. *Hickel, J., &Kallis, G. (2020). Is green growth possible? New Political Economy, 25(4), 469–486.*
13. *Huge, J., Le Trinh, H., Hai, P., Kuilman, J., Hens, L., (2010). Sustainability indicators for clean development mechanism projects in Vietnam. Environ. Dev. Sustain. 12, 561–571.*

14. *Im KS, Pesaran MH, Shin Y. 2003. Testing for unit roots in heterogeneous panels. J Econom. 115(1):53–74.*
15. *Jacobs, M., (2012). Green Growth: Economic Theory and Political Discourse (No. 92). Grantham Research Institute on Climate Change and the Environment*
16. *Kao C, Chiang MH, Chen B. 1999. International R&D spillovers: an application of estimation and inference in panel cointegration. Oxf Bull Econ Stat. 61(S1):691–709.*
17. *Karim S, Naz F, Naeem MA, Vigne SA. 2022. Is FinTech providing effective solutions to Small and Medium Enterprises (SMEs) in ASEAN countries? Econ Anal Policy. 75:335–344.*
18. *Kazzi, H. (2014), Green growth and sustainable development in the Arab countries. European Scientific Journal, 10(14), 567-568*
19. *Khan Z, Ali S, Umar M, Kirikkaleli D, Jiao Z. 2020. Consumption-based carbon emissions and international trade in G7 countries: the role of environmental innovation and renewable energy. Sci Total Environ. 730:138945.*
20. *Li, T., & Liao, G. (2020). The heterogeneous impact of financial development on green total factor productivity. Frontiers in Energy Research, 8, 29.*
21. *Lin, B., & Benjamin, N. I. (2017). Green development determinants in China: A non-radial.*
22. *M.C. Udeagha, E. Muchapondwa, (2023), Green finance, fintech, and environmental sustainability: fresh policy insights from the BRICS nations, Int. J. Sustain. Dev. World Ecol.*
23. *M.C. Udeagha, M.C. Breitenbach, 2023, Can fiscal decentralization be the route to the race to zero emissions in South Africa? Fresh policy insights from novel dynamic autoregressive distributed lag simulations approach, Environ. Sci. Pollut. Res. (2023) 1–29.*
24. *Mahat, T. J., Bl_aha, L., Uprety, B., & Bittner, M. (2019). Climate finance and green growth: reconsidering climate-related institutions, investments, and priorities in Nepal: Environmental Sciences Europe: enveurope.springeropen.com.*
25. *Mohammad Omar Alhejaili. (2024). Integrating Climate Change Risks and Sustainability Goals into Saudi Arabia's Financial Regulation: Pathways to Green Finance. www.mdpi.com.*
26. *Morssy, A. (2012), Green growth, innovation and sustainable development. International Journal of Environment and Sustainability, 1(3), 38-52.*
27. *Muganyi T, Yan L, Sun HP. (2021). Green finance, fintech and environmental protection: evidence from China. Environ SciEcotechnol. 7:100107.*
28. *Ni. Lin, Wen. Huwei, Yu. Yalu. (2023). Frontiers | Impact of fintech and environmental regulation on green innovation: inspiration from prefecture-level cities in China. www.frontiersin.org.*
29. *Obobisa ES, Chen H, Mensah IA (2022) Transitions to sustainable development: the role of green innovation and institutional quality. Environ Dev Sustain 25(7):6751–6780*

30. *Ou, J.J.-R., (2012). Construction of green competitiveness analysis index: a case study of export procession zone. Int. J. Electron. Bus. Manag. 10, 140–148.*
31. *Pesaran M. 2004. General diagnostic test for cross sectional independence in panel. J Econom. 68(1):79–113.*
32. *Pesaran MH, Yamagata T. 2008. Testing slope homogeneity in large panels. J Econom. 142(1):50–93.*
33. *PhemeloTamasiga, Helen Onyeaka, El houssinOuassou. (2022). Unlocking the Green Economy in African Countries: An Integrated Framework of FinTech as an Enabler of the Transition to Sustainability. www.mdpi.com.*
34. *PurvaKhera, Miss Stephanie Y Ng, Ms. Sumiko Ogawa, Ms. Ratna Sahay. (2021). Is Digital Financial Inclusion Unlocking Growth?.www.elibrary.imf.org.*
35. *Qian, Y., Liu, J., Cheng, Z., Forrest, J.Y.-L., (2021). Does the smart city policy promote the green growth of the urban economy? Evidence from China. Environ. Sci. Pollut. Control Ser. 28 (47), 66709–66723. quantile outlook. Journal of Cleaner Production, 162, 764–775.*
36. *Rehman, F.U., Islam, Md M., Miao, Q., 2023. Environmental sustainability via green transportation: a case of the top 10 energy transition nations. Transport Pol. 137, 32–44.*
37. *Shen, Y., Su, Z. W., Malik, M. Y., Umar, M., Khan, Z., & Khan, M. (2021). Does green investment,financial development and natural resources rent limit carbon emissions? A provincial panel analysis of China. The Science of the Total Environment, 755(Pt 2), 142538.*
38. *Song, X., Zhou, Y., Jia, W., (2019). How do economic openness and R&D investment affect green economic growth? —evidence from China. Resour. Conserv. Recycl. 146, 405–415.*
39. *SreenuNenavath, Shashwat Mishra. (2023). Impact of green finance and fintech on sustainable economic growth: Empirical evidence from India.pmc.ncbi.nlm.nih.gov.*
40. *Tajuddin, A.H., Mehmood, W., Ali, A., Mohd-Rashid, R., Aman-Ullah, A., 2023. Environmental pollution, trade balance, human development index, foreign direct investment, and natural resources rent impacts on initial public offering (IPO) variability in Pakistan: using asymmetric nardl co-integration approach. Environ. Dev. Sustain. 1–20.*
41. *Tao R, Su CW, Naqvi B, Rizvi SK. 2022. Can fintech development pave the way for a transition towards low-carbon economy: a global perspective. Technol Forecast Soc Change. 174:121278.*
42. *Tidjani. Chemseddine, Madouri. Abderazak. (2024). Frontiers | Fintech, financial inclusion, and sustainable development in the African region.www.frontiersin.org.*
43. *United Nations EnvironmentProgramme: UNEP (2018). Green Financing. www.unep.org.*

44. *Wang K-H, Zhao Y-X, Jiang C-F, Li Z-Z (2022) Does green finance inspire sustainable development? Evidence from a global perspective. Econ Anal Policy 75:412–426.*
45. *Wang Y, Lei X, Zhao D, Long R, Wu M. 2021. The dual impacts of green credit on economy and environment: evidence from China. Sustainability. 13(8):4574.*
46. *Westerlund J. 2007. Testing for error correction in panel data. Oxf Bull Econ Stat. 69(6):709–748.*
47. *World Bank Group. (2019). Islamic Green Finance: Development, Ecosystem And Prospects. documents1.worldbank.org .*
48. *YaraWajdi H. Alquliti. (2022). The Impact of Fintech, Green Finance, and Financial Inclusion on Energy Efficiency and Sustainability in GCC Countries. repository.effatuniversity.edu.sa.*
49. *Yi Li., Christy Ying Ni Liu., Ut Lao., Jiangtong Dang.,* ***(2024).*** *"Navigating the path to environmental sustainability: Exploring the role of fintech, natural resources and green energy in Belt and Road countries".*
50. *Yunqian Mo, Sana Ullah&IlhanOzturk (2023) Green investment and its influence on green growth in high polluted Asian economies: Do financial markets andinstitutionsmatter?, Economic Research-EkonomskaIstraživanja, 36:2, 2140302.*
51. *YusuffJeliliAmuda, Razan Abdullah Alamri. (2024). Green banking practices: Towards sustainable banking sector for financial inclusion in attaining Saudi Arabia's Vision 2030. systems.enpress-publisher.com.*
52. *Zhang, W., Hong, M., Li, J., Li, F., 2021. An examination of green credit promoting carbon dioxide emissions reduction: a provincial panel analysis of China. Sustainability 13 (13), 7148.*
53. *Zhang. Su. (2024). Frontiers | Empirical analysis of green finance and high-quality economic development in the Yangtze River Delta based on VAR and coupling coordination model. www.frontiersin.org.*