Journal of Infrastructure, Policy and Development 2024, 8(7), 4979.
https://doi.org/10.24294/jipd.v8i7.4979

Article

Empowering sustainable development: The crucial nexus of green fintech and green finance in Luxembourg's banking sector

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CITATION

Sohai M, Khan S, Akbar A, Svobodova L. (2024). Empowering sustainable development: The crucial nexus of green fintech and green finance in Luxembourg's banking sector. Journal of Infrastructure, Policy and Development. 8(7): 4979. https://doi.org/10.24294/jipd.v8i7.4979

ARTICLE INFO

Received: 4 March 2024
Accepted: 21 March 2024
Available online: 22 July 2024

Abstract: Luxembourg institutions have the opportunity to reconcile environmental goals with financial stability by implementing Green Fintech solutions, as the banking sector increasingly recognizes the importance of sustainability. This study employs a quantitative approach and analyzes data collected from 150 participants working in the banking industry of Luxembourg. The research aims to assess the consequences of adopting Green Fintech on sustainable development. Banking institutions can boost their financial resilience and mitigate climate-related risks by adopting Green Fintech, which improves their sustainability. The paper emphasizes the importance of Green Fintech in the Luxembourg banking sector for advancing sustainable development goals. To effectively address the increasingly complex environmental concerns, it is crucial to embrace innovative Fintechs.

Keywords: green fintech; sustainable development; green finance; Luxembourg banks, qu antitative methodology, financial stability
JEL code: G2; O1

1. Introduction

Increased resource consumption and pollution from increasing financial institutions may hinder sustainable development (Hao et al., 2020). The worldwide apprehension over climate change and environmental sustainability is intensifying, requiring immediate measures to alleviate environmental risks (Pu et al., 2024). The emergence of significant ecological problems and energy challenges poses a risk to the sustainable development of human society, hence impacting environmental stability and energy security (Wu et al., 2021). According to Song et al. (2011), environmental deterioration is intensifying due to the heavy industries' reliance on natural resources, the lack of technical innovation by state-owned firms, and their high energy consumption. The incorporation of Fintech is one example of how technological innovation affects sustainability (Hasan et al., 2023). Nosheen et al. (2021) emphasize the advantages, such as decreased expenses, enhanced operational effectiveness, and advancement towards a more environmentally friendly society. Research also suggests that advancements in technology and financial development, such as Fintech's growth, could work together to significantly reduce environmental instability (Cao et al., 2021; Nasim et al., 2023).

Advancements in technology are strongly associated with environmentally friendly development. Abid et al. (2022) and Martins et al. (2023) assert that this innovation plays a crucial role in reducing environmental impacts and accelerating the shift from traditional to sustainable economic models. The absence of bond issuing for

environmentally-friendly firms poses a hindrance to the implementation of sustainable development (Naz et al., 2024). By revolutionizing financial services, fintech is advancing green finance, sustainable development, and efficiency. As seen by projects like Ant Forest, the platform offers sustainable finance solutions. These projects highlight the need of green finance and Fintech working together to combat climate change (Cen and He, 2018). A significant decrease in industrial gas emissions and an emphasis on Fintech's role in reducing sulphur dioxide emissions are highlighted in this study on green finance policies in China (Akbar et al., 2024). China is already a leader in green finance, according to Muganyi et al. (2021), who also call for faster development of related goods and better green credit capacities. Furthermore, they advocate for Fintech companies to take part in environmental activities while also reducing systemic risks.

In recent years, the financial industry has prioritized investing in sustainable growth by integrating environmental, social, and governance (ESG) factors into investment decisions (Wu et al., 2021). The importance of ESG indicators for sustainability is highlighted, with particular attention given to ecological and social factors. The research emphasizes the significance of ecological innovation in achieving sustainability. It proposes an innovative theoretical approach that underscores the importance of sustainability reporting across industries and suggests regulators to broaden their focus on sustainability reporting regulations (Yuan et al., 2023).

The banking business sustains the financial circulation of the economy. Green financial solutions have the potential to contribute significantly to the development of a more environmentally friendly globe (Habiba and Xinbang, 2022). Green finance includes investments that yield positive environmental outcomes (Chishti and Sinha, 2022). Investing in green energy projects is vital in order to mitigate carbon pollution and its detrimental effects on the ecosystem and human health (Irfan and Ahmad, 2022).

The financial sector cannot achieve its objectives without working together on fintech and ensuring the effective deployment of resources. Significant structural changes in China's energy, economic, and environmental sectors are necessary to achieve green environmental goals. According to Awais et al. (2023), it is crucial to implement Fintech and other eco-friendly technologies to meet environmental objectives. The negative effects of technological progress on the environment have been recognized for a significant period (Yang et al., 2021). Transitioning to a paperless economy can be achieved gradually by using advanced fintech technologies, as suggested by Arner et al. (2020). Yang et al. (2021) found that Fintech positively impacts environmental preservation and the economic framework, leading to the promotion of high-quality sustainable economic development.

This study explores China's sustainable development efforts. It shows how economic growth, resource exploitation, financial system development, trade openness, and GHG emissions are linked. The major findings show a curvilinear relationship between wealth and greenhouse gas (GHG) emissions, with natural resource use benefiting and financial development hurting. To address environmental issues and achieve Sustainable Development Goals (SDGs), the study recommends cleaner technologies, resource optimization, financial development, and trade openness (Ze et al., 2023).

Investing in green projects has the effect of decreasing carbon pollution in both the short and long term. These investments facilitate the implementation of renewable energy and energy efficiency measures, resulting in a rapid reduction in emissions. Investing in green initiatives over an extended period of time aids in the advancement and implementation of cutting-edge technology and sustainable methods, resulting in a decrease in carbon emissions and the alleviation of climate change (Li et al., 2021). Green financing can provide advantages to impact investors by supporting environmentally sustainable businesses, aligning with market trends, and safeguarding financial stability (Barber et al., 2021). Green financing promotes energy efficiency and green buildings while decreasing funding for fossil fuel operations, therefore assisting in the development of a carbon-neutral economy and aligning financial strategies with climate goals (Ozili, 2022). Green financing enables businesses and governments to engage in various sustainable initiatives, expand their investment portfolios, mitigate risk, and take advantage of opportunities in the green economy (Reboredo, 2018). This study seeks to examine the potential of green Fintech in advancing sustainable development from the standpoint of green finance (Shah et al., 2023).

Udeagha and Muchapondwa (2023) underscore the significance of green finance and Fintech in advancing environmental sustainability within the BRICS nations through their research findings. Additionally, the Sustainable Development Goals emphasize the need for increased research and development in this field.

The study's goals are as follows: to assess how the banking sector in Luxembourg is utilizing Green Fintech to promote sustainable development. The goal of this study is to examine how Green Fintech has affected green finance within the Luxembourg banking sector, assess the correlation between sustainable development and green finance within the Luxembourg banking industry and examine the mediating role of green finance in the Luxembourg banking sector between sustainable development and green fintech.

The paper's structure is as outlined below: The following sections describe the literature review (Section 2), methodology (Section 3), research findings (Section 4), discussion (Section 5), implications, limitations, future directions, and conclusion.

2. Literature review

Green finance is a relatively new subject of study, but experts have already recognized it as a crucial tool for attaining sustainable development and energy security. When making loan choices, post-monitoring, and risk assessments, green bankers must take environmental issues into account, in contrast to conventional financiers. By contrast to "Internet finance," "Fintech" lays greater emphasis on how conventional financial activities are strengthened by incorporating current technology, rather than merely on the Internet (Goldstein et al., 2019). The term "Fintech" encompasses a broader trend within finance, which involves advancements in areas such as peer-to-peer lending, insurance, debt markets, payment processors (with a focus on cryptocurrencies), and other related fields (Anagnostopoulos, 2018).

Eco-friendly Green Fintech can handle many people with big data analysis, IoT, machine learning, AI, mobile payment technologies, and their benefits without charging extra. Green Fintech companies reduce carbon dioxide (CO_2), foster shared

automobiles, and reduce carbon consumption through the sharing economy (Mi and Coffman, 2019). Green Fintech solutions like London's peer-to-peer food sharing enterprise reduce food waste and green gas emissions (Makov et al., 2020). Furthermore, green financial technologies have the capacity to efficiently assist financial institutions in monitoring and selecting green initiatives, as well as estimating their environmental impact (Yang et al., 2020).

Sustainable Development entails creating a plan to achieve human development objectives while also guaranteeing the durability of natural systems to sustainably supply necessary resources and ecosystem services desired by the economy and society (Lélé, 1991).

Researchers have demonstrated that the financial sector has a substantial impact on the dynamics of the economy (Karim et al., 2022), and that advancements in this field contribute to the achievement of green growth goals (Yang and Ni, 2022). According to Ahmed et al. (2022), the growth of the economy is contingent upon the occurrence of this kind of development over the course of time. When it comes to the tangible economy, innovations in fintech help keep it growing by making companies more productive overall (Luo et al., 2022; Shaik et al., 2023). Fintech utilises advanced technology like blockchain for secure transactions, cloud computing for scalable services, and artificial intelligence for data analysis and automation, thereby transforming the financial industry (Zhou et al., 2022). Fintech enables more efficient resource allocation by implementing digital workflows, hence minimising the use of paper and decreasing the carbon emissions often connected with conventional financial activities (Moro-Visconti et al., 2020). Fintech plays a vital role in supporting the UN's vision for sustainable development by encouraging financial inclusion, enhancing access to capital, and facilitating effective resource allocation (Merello et al., 2022).

Wang et al. (2023) explored the differential influence of artificial intelligence and natural resource management on the sustainable export value. While positive shocks in resource management improve export value, negative shocks in AI have a larger impact, highlighting the prevalence of asymmetric interactions.

Pu et al. (2024) investigates the impact of fintech, natural resources, and the banking sector on climate change and environmental sustainability. Empirical data suggests that the existence of ample natural resources acts as a catalyst for the expansion of the banking sector, therefore exacerbating the issue of climate change. In contrast, fintech has a substantial negative effect on sustainability, whereas the financial industry's contribution is negligible. Suggested measures consist of advocating for sustainable lending, allocating resources towards fintech research, and implementing stringent laws on natural resource usage (Pu et al., 2024).

According to Thakor (2020), blockchain technology makes a substantial contribution to advancements in Fintech. The SDGs and the Paris Agreement pledges can only be met with the help of green financing, which fintech, and blockchain in particular, can make possible. Fintech is essential for achieving sustainable development goals and green finance (Kayani et al., 2023; Martins et al., 2022; Nassiry, 2018).

Fintech may significantly improve the financial industry by advocating for eco-friendly financial practices including green investments and financing (Ahmed and

Huo, 2021; Zhou et al., 2022). This is significant because the banking sector relies on both environmental sustainability and economic growth (Afzal et al., 2022). However, it is currently acknowledged that the banking sector plays a crucial role as the main provider of financing for business ventures and makes a substantial contribution to the overall economic expansion. Consequently, it has a vital function in facilitating investments in sustainable environmental development and social responsibility (Pham, 2018). Financial institutions actively provide green credits for environmentally beneficial initiatives and prioritize green sectors (Garg and Sharma, 2017).

Xu et al. (2022) and Choudhury et al. (2023) discovered an inverse relationship between lending rates and carbon emissions, where higher lending rates lead to a decrease in emissions, but increased credit availability results in higher emissions. Fintech's focus on digitalization, as examined by Lee et al. (2023), in addition to paperless transactions, as demonstrated by Kaur et al. (2021), helps create a more sustainable future by encouraging effective online processes, lowering reliance on physical resources, and minimising environmental footprints. According to Tan et al. (2023), Credit market innovation facilitates the provision of inclusive financial services, promoting economic progress in disadvantaged communities and aligning with sustainable development goals for ensuring access to financial services. These developments play a crucial role in improving the operating efficiency of the financial sector. This helps to promote environmental conservation by reducing paper waste and minimising fuel usage during transit.

Shan et al. (2024) examined the influence of Fintech innovation, resources of nature, and human capital on the long-term preservation of the environment in BRICS countries. It highlights the efficacy of Fintech in decreasing greenhouse gases in the banking industry and emphasizes the significance of human resources in promoting sustainable innovation. Policy suggestions propose the implementation of environmental rules, the promotion of green financing through Fintech, the introduction of carbon taxes, and the provision of subsidies to facilitate the transition to green energy in BRICS nations.

Financial institutions, both public and private, are able to increase the sales of green credits thanks to Fintech advancements (Nenavath, 2022; Yang et al., 2021). This advancement will be beneficial to capital development and green financing. However, extensive usage of green funding can have unexpected negative effects on the environment. Green finance is required to motivate more businesses and entrepreneurs to take steps towards operational sustainably. Reallocating funds to green projects, equities, and bonds contributes to this goal while also greatly improving environmental conditions (Qin et al., 2024).

The development of green finance has been propelled by the emergence of Fintech, leading to the dissemination of technological benefits. Le et al. (2021) suggested that Fintech, as a newcomer in the market, could offer unique advantages in encouraging the development of green bonds. These bonds are essential for investors to diversify their holdings. Goodell et al. (2022) established a significant correlation between Fintech and green indices, demonstrating that Fintech technologies such as

Artificial Intelligence (AI) and Machine Learning (ML) can direct investments towards eco-friendly initiatives. The technological spillover theory, proposed by Ning et al. (2023), explains how Fintech and green credit in the banking industry interact and how advances in one area typically benefit others. Green finance, and green financing in particular, is impacted by Fintech developments in this sector. Fintech facilitates sustainable development by facilitating green financing, minimizing expenses and information imbalances, enhancing productivity, assessing the worth of natural resources, and advocating for practical approaches to sustainable lifestyles. Fintech enables the attainment of green finance (Cen and He, 2018).

The study seeks to analyse the impact of several components of green finance, such as green credit, renewable energy production, creativity, eco-innovation, and economic growth, on sustainable development goals. Renewable energy reduces CO_2 and helps sustainable development (Sadiq et al., 2023). The concepts of green finance and sustainability are closely linked and crucial for achieving global sustainability. The financial sector actively encourages and supports green finance initiatives to ensure long-term environmental sustainability. The effectiveness of green finance is diminished in the absence of sustainable development (Agirman and Osman, 2019).

According to Shahzad and Riaz, (2022), allocating more funds towards renewable energy sources, coupled with efforts to conduct research and development and collaborations between the public and commercial sectors, results in a decrease in CO_2 emissions. This statement highlights the importance of utilizing green finance in the renewable energy sector to attain environmental sustainability. It also promotes the idea of international trade of renewable energy as a means to reduce world CO_2 emissions. In addition, the study offers rankings of regions according to their environmental sustainability, providing valuable information for recruiting foreign and private investment in sustainable ventures.

Green finance enhances both the global economy and the environment. Underdeveloped regions might derive greater advantages from improving their environmental performance through the utilization of green finance, primarily because they face challenges in accessing well-established credit and capital markets. Green financing facilitates the advancement of eco-friendly innovation and offers assistance to regions without access to money for environmental initiatives. It hinders the progress of environmentally friendly products in developed countries with robust green technology or sustainability regulations (Ma et al., 2023). This study investigates the influence of green finance and environmental degradation on the long-term viability of developing nations. Environmental degradation impedes the achievement of sustainable progress, while green investments facilitate it (Hunjra et al., 2023).

2.1. Hypothesis

H1: Green Fintech positively influences sustainable development in the banking sector of Luxembourg.

H2: Green Fintech significantly enhances green finance initiatives within the Luxembourg banking system.

H3: A statistically significant correlation exists between sustainable development and green finance in Luxembourg's banking sector.

H4: Green Finance serves as a mediator between Green Fintech and sustainable development in Luxembourg's banking industry.

2.2. Theoretical framework

Figure 1 exhibits Green Fintech impacts Green Finance in this paradigm, improving the effectiveness and availability of sustainable financial processes. Green Finance actively contributes to friendly Development by allocating funds towards ecologically friendly enterprises. Furthermore, Green Fintech indirectly promotes Sustainable Development by facilitating the efficient functioning and growth of Green Finance, highlighting the interdependent role of fintech in advancing sustainability objectives.

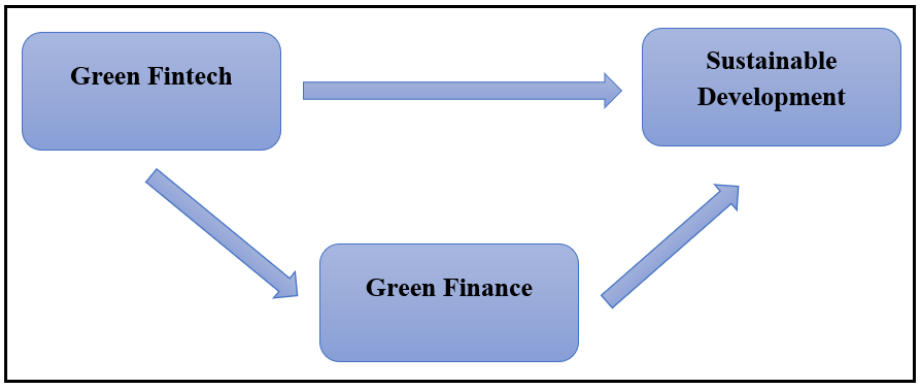

Figure 1. Theoretical framework.

3. Methodology

The research participants were carefully selected from a variety of roles inside Luxembourgish Fintech companies and banking institutions using a stratified random selection approach. Stakeholders included a wide range of individuals, including administrators, managers, financial analysts, and information technology specialists. Official websites, conferences, Fintech expos, and LinkedIn were among the platforms used. In order to achieve a varied sample of 150 persons, a meticulous and thorough technique was employed. The questionnaire was segmented into three distinct sections: Section A requested demographic information, Section B delved into topics regarding green finance, and Section C investigated attributes associated with sustainable development. The data analysis was conducted using SPSS Version 21. Prior to distributing the questionnaire to the participants, they were provided with a comprehensive explanation of the study's objectives and their rights, ensuring that they gave their informed consent. The research endeavor included both a commitment to ethical standards and rigorous data protection measures.

A group of 150 individuals has been chosen to represent the unique atmosphere of Luxembourg's fintech sector. This decision is impacted by the distinctive characteristics of the industry and its comparatively smaller size. Obtaining a bigger sample size is impractical due to constraints such as budget limitations and restricted availability of participants. However, the study maintains its credibility and relevance

by using robust sampling procedures and assuring representation across broad demographic groups. The research offers unique insights into the dynamics of Luxembourg's financial landscape by placing a high importance on methodological rigor and data integrity.

4. Research findings

4.1. Descriptive analysis

4.1.1. Gender analysis

The study consisted of 63 female participants and 87 male participants, indicating an equitable level of interest in ethical banking. The widespread participation demonstrates a growing awareness and interest in making sustainable financial and investing decisions.

4.1.2. Working experience

Figure 2 represents that 69% of Luxembourg bankers have been in the industry for more than 15 years. This sizable group ensures the continuity and development of the industry by providing domain-specific knowledge, abilities, and experience. Only seven percent of those who contribute have more than five years of experience, but their fresh ideas and perspectives are valuable. Having people with different levels of experience working together allows for a more robust ecosystem that can respond to the dynamic nature of Luxembourg banking sector.

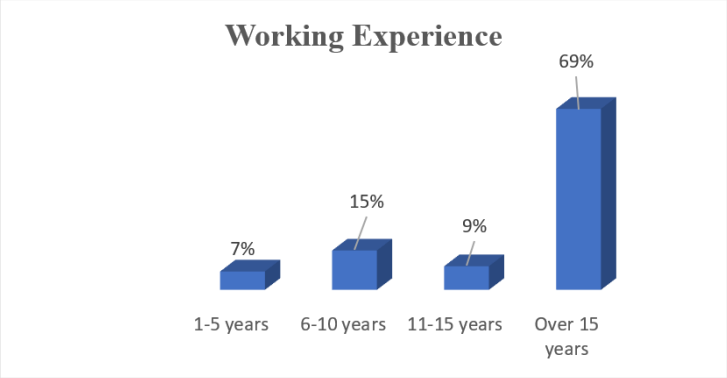

Figure 2. Working experience of respondents.

4.2. Correlation analysis

The coefficient varies between –1 and 1. A correlation value closer to 1 or –1 indicates a higher link between the variables. There is less association if the coefficient is near to zero. Correlation analysis is displayed below in **Table 1**.

Table 1. Correlations analysis.

	Green Finance	Sustainable Dvp	Green Fintech
Green Finance	1		
Sustainable Dvp	0.723**	1	
Green Fintech	0.684**	0.754**	1

**. Correlation is significant at the 0.01 level (2-tailed).

The relationship between sustainable development and green Fintech is significantly positive, with a correlation coefficient of 0.754 and a significance level of $p < 0.01$. There is a strong correlation between sustainable development and adoption of green fintech. There is a positive correlation between the rise of sustainable development efforts and an increase of green fintech operations. Hence, H1 is supported.

Green finance and green fintech exhibit a significant and positive relationship, with a correlation coefficient (r) of 0.684 and a *p*-value less than 0.01. This is a significant association between green finance efforts and adoption of green fintech. Green fintech initiatives anticipate a rise in green finance, and vice versa. Hence, H2 is supported.

Green finance and sustainable development show a statistically significant positive association ($r = 0.723$, $p < 0.01$). This is a significant correlation between green finance activities and sustainable development. Green financing tends to increase sustainable development initiatives, and vice versa. Hence, H3 is supported.

4.3. Regression analysis

In this regression analysis, green finance serves as a mediator between sustainable development and green Fintech. Andrew F. Hayes' process macro analysis (v4.2) is used in this subsection to determine the causes and effects between the independent and dependent variables (Hayes, 2017).

The findings in **Table 2** show strong evidence of a significant connection between green fintech and green finance. The analysis reveals that green fintech has a significant impact on green finance, as indicated by an *R*-squared value of 0.3724. This value suggests that about 37.24% of the observed variance in green finance can be attributed to green fintech. The model's high level of significance, indicated by a *p*-value of 0.0000, emphasizes the strength and reliability of this association. The coefficient for green fintech is precisely 0.2515, indicating a statistically significant and positive correlation with green finance. The results highlight the crucial importance of green fintech developments in promoting environmentally sustainable financial practices.

Table 2. Outcome variable-green finance.

Model Summary							
	R	*R*-sq	MSE	*F*	df1	df2	*p*
	0.6102	0.3724	0.6712	53.2657	1.0000	148.0000	0.0000
Model							
	coeff	se	*t*	*p*	LLCI	ULCI	
Constant	2.9801	0.3123	9.5338	0.0000	2.3606	3.5996	
FNTCH	0.2515	0.0451	5.5763	0.0000	0.1624	0.3406	
Standardized coefficients							
	coeff						
FNTCH	0.6102						

The correlation coefficient (R) of 0.5913 indicates a moderate to strong positive linear association between green financing, green fintech, and sustainable development as shown in **Table 3**. This suggests that the rise of green financing and green Fintech is correlated with an increase in sustainable development. The *R*-squared value is relatively high, suggesting that roughly 34.96% of the variation in sustainable development may be attributed to green finance and green fintech. This implies that the model offers a fairly accurate match to the data. The extremely low *p*-value of 0.0000 indicates that the model's overall significance is extremely important, suggesting a highly significant statistical relationship between the independent variable and the dependent variable.

Table 3. Outcome variable-SD.

Model Summary							
	R	*R*-sq	MSE	*F*	df1	df2	p
	0.5913	0.3496	0.3198	39.5149	2.0000	147.0000	0.0000
Model							
	coeff	se	*t*	*p*	LLCI	ULCI	
Constant	1.2977	0.2851	4.5512	0.0000	0.7342	1.8612	
FNTCH	0.3093	0.0525	5.8883	0.0000	0.2055	0.4131	
GF	0.3194	0.0560	5.6987	0.0000	0.2086	0.4301	
Standardized coefficients							
	coeff						
FNTCH	0.3962						
GF	0.3834						

Table 4 shows $R = 0.4538$ which suggests a moderate positive linear relationship between green fintech and sustainable development. The positive sign indicates that as the green fintech increase, sustainable development tends to increase as well. The *R*-squared value of 0.2060 suggests that green fintech explain about 20% of the variance in sustainable development. Although not incredibly high, it is indicative of the model's ability to explain the correlation. However, the model's overall significance, indicated by the remarkably low *p*-value, supports the existence of a statistically significant association between green fintech and sustainable development. This emphasizes the significance of green fintech as a forecaster of sustainable development.

Table 5 shows the total effect of green fintech on sustainable development, the value of 0.2515 for the mediation effect indicates that green finance plays a significant role in bridging the gap between Luxembourg's banks' adoption of fintech and their commitment to sustainable development. This positive value suggests that the general adoption of green fintech aids in sustainable development because of the mediating effect of green finance. The *p*-value associated with the *t*-statistic is 0.0000.

The direct impact indicates the probability of observing a mediation effect as extreme as the one estimated if there were no actual mediation. The direct effect value of 0.1410 indicates that green Fintech adoption has a significant positive direct effect on sustainable development. In practical terms, this means that an increase in green

fintech adoption within Luxembourg banks is associated with a measurable and statistically significant increase in their sustainable development efforts. The *p*-value of 0.0000 associated with the t-statistic indicates the probability of observing a direct effect as extreme as the one estimated if there were no actual direct effects.

Table 4. Total effect model (Outcome Variable-SD).

Model Summary						
R	***R*-sq**	**MSE**	***F***	**df1**	**df2**	***p***
0.4538	0.2060	.3878	38.3896	1.0000	148.0000	0.0000
Model						
coeff	**se**	***t***	***p***	**LLCI**		**ULCI**
constant 2.3500	0.2393	9.8209	0.0000	1.8771		2.8228
FNTCH 0.3543	0.0572	6.1959	0.0000	0.2413		0.4673
Standardized coefficients						
	coeff					
FNTCH	0.4538					

Table 5. Total, direct, and indirect effects of FNTCH on SD.

Total effect of FNTCH on SD						
Effect	se	*t*	*p*	LLCI	ULCI	c_cs
0.2515	0.0451	5.5763	0.0000	0.1624	0.3406	0.6102
Direct effect of FNTCH on SD						
Effect	se	*t*	*p*	LLCI	ULCI	c_cs
0.1410	0.0762	1.8509	0.0000	0.0095	0.2915	0.1504
Indirect effect(s) of FNTCH on SD						
	Effect	BootSE		BootLLCI		BootULCI
GF	0.1105	0.0346		0.0422		0.1854
Completely standardized indirect effect(s) of FNTCH on SD						
	Effect	BootSE		BootLLCI		BootULCI
GF	0.1427	0.0442		0.0531		0.2378

Note(s): Abbreviation: Green Fintech (FNTCH), Green Finance (GF), Sustainable Development (SD), Lower Limit of Confidence Interval (LLCI), Upper Limit of Confidence Interval (ULCI).

A value of 0.1105 is assigned to the indirect effect of green fintech on sustainable development through green finance. This indicates that the connection between green fintech and sustainable development is influenced by green finance. The broad use of green fintech, which helps green financing, supports sustainable development. The indirect impact is statistically significant because the confidence interval (from BootLLCI to BootULCI) does not contain zero.

The completely standardized indirect effect of green fintech on sustainable development through green finance is 0.1427. This shows how green finance mediates the standardized effect of green Fintech on sustainable development. There is statistical significance in both the indirect effect and the completely standardized indirect effect.

Overall, these results indicate that there is statistically significant support for both the direct as well as indirect impact of green fintech on sustainable development mediated through green finance. This emphasizes the significance of developing green finance as a mediator in the relationship between sustainable development and green Fintech. Hence, H4 is supported.

5. Discussion

The findings of the quantitative analysis revealed that there is a significant and positive connection between green fintech and sustainable development. Fintech has the potential to promote environmental sustainability, as confirmed by research findings (Lisha et al., 2023; Murshed, 2024; Xia and Liu, 2024). Modern financial institutions can do better for the environment if they combine cutting-edge innovation with eco-friendly procedures. The use of natural resources has allowed several nations to significantly increase their economic growth, according to the available evidence. Because of their dependence on outdated, inefficient, and technologically backward conventional sectors, we have seen alarming levels of pollution (Haddad and Hornuf, 2019; Song et al., 2011).

Innovations in the Fintech sector have a major impact on sustainable development through improving environmental quality and decreasing energy usage. The green environmental index and fintech have been proven to have a positive and statistically significant connection (Nenavath and Mishra, 2023). In addition to impacting economic growth and pollution levels, technological innovation also has the dual effect of decreasing and rising expenses, which in turn fosters sustainable development (Jin and Han, 2018). Fintech innovations are making financial resources more accessible, which is helping to improve green finance and sustainable development efforts. A successful investment mechanism that can both build long-term wealth and reduce carbon emissions is what proponents of green bonds believe. Sustainable funding and distribution processes are made possible by the consolidation of contributions from several persons, typically through digital payment systems and online platforms (Anshari et al., 2019).

The study examines the crucial role of Fintech in improving economic well-being in the face of global issues, particularly the pandemic. The findings indicate that the utilization of natural resources and the implementation of Fintech have the potential to decrease carbon emissions. Research promotes the use of environmentally sustainable solutions and emphasizes the importance of policymakers prioritizing Fintech and the sustainability of natural resources (Kai et al., 2024).

Nenavath and Mishra (2023) argue that green finance enables corporations and enterprises to invest in ecologically sustainable initiatives, stocks, and bonds, thereby promoting the improvement of environmental quality. Zhou et al. (2022) argue that green funding is essential for addressing knowledge gaps that pose a danger to sustainable development, as well as for supporting resource conservation and environmental protection. Green finance has been shown to make a substantial contribution to sustainable development through its enhancements to economic structures, performance, and environmental health (Tawiah et al., 2021).

Fintech's novel concepts and technical advancements greatly enhance sustainable development. Fintech enhances information symmetry, hence increasing the accessibility of credit-related knowledge to firms and reducing financial barriers. Digital transformation is at the core of fintech, which incorporates a broad variety of technologies such as cloud computing, blockchain, Big Data, the Internet of Things, and artificial intelligence. Research indicates that the progress of ecosystems can be accelerated with the use of fintech upgrades, which involve enabling more efficient educational financing, increasing financial support, and enhancing resource allocation (Gu et al., 2021). This helps bring us closer to the sustainable development objectives in the end.

The role of fintech in green financing mediation has been uncovered; it partially mediates between green investment and green credit, which in turn affects the green environmental index's trajectory (Nenavath and Mishra, 2023). The results also demonstrate that green finance is a key link in the chain connecting green Fintech to sustainable development. By incorporating environmental considerations into financial decision-making processes, green finance amplifies the beneficial effects of green fintech on sustainable development results. This allows for the allocation of cash towards sustainable activities.

6. Implications for practice

The findings not only have implications for various political leaders, but they also have repercussions for various financial entities. The adoption of green Fintech solutions, the implementation of green finance principles into banking operations, and the identification of themselves with sustainability objectives are all ways in which institutions have the ability to aid in the promotion of both innovation and financial stability. Additionally, the adoption of green finance has brought to light the necessity of regulatory frameworks and incentives that encourage environmentally responsible behavior among financial firms. This has been brought to light when green finance was implemented.

7. Limitations

Several limitations are identified by the study. To start with, there may have been limits in the data's availability or quality that rendered the analysis unreliable, even though data accuracy was assured. In addition, the results may not be generalizable to other financial situations if they are confined to the banking business in Luxembourg. Furthermore, nuanced qualitative findings or relationships may go overlooked if quantitative procedures like regression and correlation analysis are relied upon entirely. It is also possible that the research did not include all important factors influencing Green Fintech's impact on sustainable development.

8. Future directions

Performing additional qualitative research could provide valuable insights into the factors that influence the adoption of green fintech in the banking industry of Luxembourg, as well as the results of this adoption. It is possible that a long-term

review could provide substantial insights on the success of green fintech programs over the long term. It is possible that innovation could be stimulated by collaboration between financial institutions, information technology companies, legislative bodies, and environmental organizations. It is essential to do a comprehensive analysis of the regulatory frameworks and incentives that enable the adoption of green fintech. For the sake of advancing sustainability on a global scale, it is essential to conduct an analysis of the scalability of successful green finance projects.

9. Conclusion

The study's findings emphasize the crucial significance of green finance in enabling the positive correlation between sustainable development and green fintech. Green finance plays a vital role in facilitating the adaptation of fintech breakthroughs into meaningful contributions to sustainable development objectives by acting as a mediator. Therefore, financial institutions that aim to achieve their sustainability goals must make it a priority to prioritize fintech solutions that are environmentally friendly. By implementing progressive ideas and adopting environmentally conscious practices, banks and other institutions can actively engage in efforts to preserve the environment and promote sustainable growth initiatives. This proactive approach not only corresponds to regulatory patterns but also emphasizes the potential for financial institutions to become influential catalysts of positive environmental transformation. In order to maximize the benefits of green fintech and green finance, it is essential to prioritize research and collaboration to enhance their potential. This is expected to result in greater opportunities and development in sustainable financial projects, leading to a more ecologically responsible and sustainable financial ecosystem.

Author contributions: Conceptualization, MS; methodology, MS; software, MS; validation, MS, SK and AA; formal analysis, MS; investigation, LS; resources, LS; data curation, AA, SK; writing—original draft preparation, MS; writing—review and editing, AA, SK; visualization, MS; supervision, LS; project administration, LS, AA, SK; funding acquisition, LS, SK. All authors have read and agreed to the published version of the manuscript.

Data availability statement: The raw data supporting the conclusions of this article will be made available by the authors without undue reservation.

Informed consent statement: Informed consent was obtained from all subjects involved in the study.

Acknowledgments: This study is supported by the internal project "SPEV—Economic Impacts under the Industry 4.0, Societies 5.0 & 6.0 Concept", 2024, University of Hradec Králové, Faculty of Informatics and Management, Czech Republic. Authors would like to express gratitude to Petra Skorepova for her contribution to this research.

Conflict of interest: The authors declare no conflict of interest.

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