



**FINANCIAL TECHNOLOGY AND GREEN TRADE: INVESTIGATING THE MEDIATING
ROLE OF FINANCIAL INCLUSION AND FINANCIAL LITERACY**

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Abstract

This study investigates the effect of financial technology (Fintech) on green trade. We also evaluate the mediating role of financial inclusion and financial literacy in explaining the effect of fintech on green trade. We collect a panel of country-level data from 2010 to 2023. The current study deployed the structural equation model to estimate the results. Results reveal that fintech does not have a direct effect on green trade, while financial inclusion improves green trade. In contrast, financial literacy discourages green trade. The results also show that financial inclusion significantly improves the effect of fintech on green trade. However, financial literacy does not mediate the relationship. The extended results show that the mediating role of financial inclusion is similar among male and female using fintech and having access to financial services. While the mediating role of financial inclusion deviates among young and adults, and lower and higher qualified population, when analysing the effect of fintech on green trade. While the fintech-financial inclusion mediation effect is significant for green exports and net green exports but weak for green importing countries. The moderation -mediation analysis shows that the mediating role of financial inclusion in explaining the fintech and green trade relationship deviates among urban and rural populations, with level of population growth and with countries' per capita income. Results are consistent with alternative proxies of fintech and financial inclusion. Results are similar when estimating the results with alternate estimator.

Keywords: Fintech, Financial Inclusion, Financial Literacy, Green Trade

JEL Classification: F14, F19, G21, O33

1. Introduction

The emerging concerns regarding global issues like the green economy and green business have increased the policy concerns towards sustainable development (SDG, 2025). Among others, green trade is one of the crucial global societal and economic challenges to achieve sustainable development. Practitioners and researchers across the world are interested in how green trade may influence the larger sustainability goals (Danladi et al., 2023). For instance, the existing studies investigated the market acceptability of green materials in the global markets (Le Ferrand, 2024), the role of green trade in influencing the environment (Bai et al., 2023; Hek et al., 2024) and air quality (Van Hinsberg & Can, 2024). However, studies are limited in



explaining the emerging parallel practices, which may influence green trade for addressing the sustainability goals.

One such practice is Financial Technology (Fintech). Researchers and practitioners are increasingly focusing on the role of financial technology (FinTech) in addressing sustainable development issues. Fintech has the potential to enhance financial literacy among people and help the rapid transfer of funds among economies, which leads to sustainable development (Kesavan & Polisetty, 2025). In addition, Fintech can also help the world to achieve the Sustainable Development Goals through financial inclusion. Fintech helps achieve sustainable development when a well-designed infrastructure of access to finance is available (Arner et al., 2020).

The higher fintech facilitation establishes the environment for enhanced financial literacy and financial inclusion. An economy with higher financial literacy and financial inclusion will have the potential for higher green finance, an improved level of green investment and resultantly increased green trade. The financial experts, policymakers and practitioners engineered financial products such as green finance and green investment that help improve the global environment, reduce carbon emissions and mitigate climate change (Ghouse et al., 2025). Fintech has the potential to enhance the accessibility and availability of green trade through financial inclusion and financial literacy.

The existing studies have determined that green trading is inevitable for improving environmental quality (Van Ledden et al., 2024). However, the extant studies are limited in explaining the direct role of fintech and the mediating roles of financial inclusion and financial literacy for determining the behavior of green trade. Therefore, this study investigates whether fintech increases green trade and whether financial inclusion and financial literacy improve the relationship between fintech and green trade.

We utilized country-level annual panel data from 2011 to 2023. We estimated the results through the Panel Structural Equation Model (SEM) (Ghouse et al., 2025). We extended the study by classifying the fintech users in terms of gender, the financial inclusion by gender, age, education and economic class, and the green trade among green exports, green imports and net green exports. We further classified the aggregate sample into the level of urban population ratio, population growth and income level. To test the robustness of our proxies, we utilized the alternative proxies of fintech and financial inclusion. This study reexamined the results through the Causal Equation Model to ensure robustness.

Our detailed investigation provided thirteen important findings. 1) Fintech does not directly affect the green trade, 2) financial inclusion significantly improve the green trade, 3) financial literacy discourages the green trade, 4) financial inclusion significantly improves the effect of fintech on green trade, 5) financial literacy does not mediate the effect of fintech on green trade, 6) the mediating role of financial inclusion on the relationship between fintech and green trade, is similar in male population using fintech with female population, 7) the results are consistent when male and female population having the access to finance, 8) the mediating role of financial inclusion between fintech and green trade is stronger when working group is having access to finance compared to young group, 9) these results are stronger when financial inclusion is higher among secondary education population compared to primary educated population, 10) the mediating role of financial inclusion is significant while explaining the effect of fintech on green exporting and net green exporting countries but insignificant for green importing countries, 11) financial inclusion negatively mediates the effect of fintech on green trade among rural population, 12) the financial inclusion improves the fintech–green trade relationship in countries with low population, and 13) this mediating role is positive in high income countries while negative in low income countries. Results are consistent with alternative proxies of fintech and financial inclusion. Results are similar when estimating the results with alternate estimators.

Our study results contribute to six considerable aspects of sustainable finance and economics. First, this study adopted the Green Finance Openness Index developed by Can, Ben Jebli, et al. (2022) while extending the scope of the index to a large set of countries. The extension of the index will help future researchers utilize the index for investigating the green trade in other regional studies. Second, our results suggest that financial inclusion significantly improves the effect of fintech on green trade. These results suggest that policies should be aligned to improve fintech in conjunction with access to finance for improving



the green trade for enabling green economy initiatives. Third, the results suggest that efforts should be exerted to improve the financial inclusion among the working-age group and to people with higher qualifications, for facilitating the fintech in improving the green trade. Fourth, our results suggest that the conjunction of fintech and financial inclusion increases the green exports and net green exports. Hence, policies in green exporting countries may be developed for improved fintech infrastructure development and enhancing financial inclusion among the population. Fifth, our results also inform that the financial inclusion mediating role is significant in countries with low population growth. Therefore, economies with low population growth should also improve fintech and financial inclusion to enhance the green trade. On the other hand, economies with high population growth should also exert their efforts to redirect the potential of fintech and financial inclusion towards the green trade economy. Sixth, according to our results, the mediating role of financial inclusion in improving the effect of fintech on green trade is positive only in high-income countries, but negative in low-income countries. These results also indicate that high-income countries should focus more on improving fintech and financial inclusion to enhance green trade, while low-income countries should invest substantial effort in shaping the nexus among fintech, financial inclusion, and green trade.

The remainder of the article is as follows. Section two details and critically evaluate the theories leading to our hypothesis. Section three reports the study methodology. Section four includes the results and discussion, and section five concludes the study.

2. Theoretical Background

The current study evaluates the theoretical background with two different aspects. First, we report on the theoretical understanding of the relationship between fintech and green trade through the financial inclusion channel. Secondly, we attempt to theoretically understand how financial literacy develops the relationship between fintech and green trade.

2.1 Green Finance Theory

This study assumes and tests the influence of fintech on green trade through the mediating role of financial inclusion. We build our theoretical understanding of the proposed relationship through the green finance theory (Akbar et al., 2024). Sandberg (2018) explains that financial managers should prioritize two goals while making a financial decision: i) a general aim to achieve the social and environmental targets for the larger benefits of society and ii) a specific aim of profitability. The firms and economies should grow while bringing a balance in achieving both goals. If the specific goals hinder long-term sustainability, they should not be considered for implementation. Financing unsustainable projects may be prone to long-term risk as well (Schoenmaker, 2018). We assume that fintech has the potential to achieve the general as well as the specific goals. Fintech enhances access to finance; a better environment of financial inclusion improves the capability to increase green trade (Arner et al., 2020; Danladi et al., 2023).

2.2 Financial Literacy Theory

We also attempt to investigate the mediating role of financial literacy in determining the effect of fintech on green trade. Though the green finance theory may also elucidate the role of financial literacy, we evaluate this role through the lens of financial literacy theory (Akbar et al., 2024). Fintech is a facility that provides an easier solution to financial services. However, understanding financial services requires financial literacy. Higher fintech facilities educate society while using financial services. The resultant higher financial literacy brings economic growth (Lusardi & Mitchell, 2013). We assume that fintech enhances financial literacy, and in turn, improved financial literacy promotes the green trade. With the increase in the digital services environment, a tendency to increase financial literacy provides a platform for improved green trade (AlSuwaidi & Mertzanis, 2024; Ellili, 2023; Khan et al., 2022; Kishor et al., 2024).

3. Study Methodology

3.1 Methodology and Economic Model

We deployed the Panel Structural Equation Model for investigating the mediation of financial inclusion and financial literacy while evaluating the effect of fintech on green trade (Ghouse et al., 2025). For this purpose, we employed the following economic model.



$$GTOI_{it} = \beta_0 + \beta_1 FT_{it} + \beta_2 FI_{it} + \beta_3 FL_{it} + \beta_4 GFCF_{it} + \beta_5 FDI_{it} + \beta_6 EU_{it} + \beta_7 \text{LogGDPPC}_{it} + \beta_8 PG_{it} + \varepsilon_{it}$$

Direct Effect (1)

$$FI_{it} = \alpha_0 + \alpha_1 FT_{it} + \alpha_2 GFCF_{it} + \alpha_3 FDI_{it} + \alpha_4 EU_{it} + \alpha_5 \text{LogGDPPC}_{it} + \alpha_6 PG_{it} + \mu_{it}$$

Indirect Effect through *FI* (2)

$$FL_{it} = \gamma_0 + \gamma_1 FT_{it} + \gamma_2 GFCF_{it} + \gamma_3 FDI_{it} + \gamma_4 EU_{it} + \gamma_5 \text{LogGDPPC}_{it} + \gamma_6 PG_{it} + \mu_{it}$$

Indirect Effect through *FL* (3)

GTOI stands for Green Trade Openness Index, FT represents the FinTech, FI is the financial inclusion, FL reflects the financial literacy, GFCF means gross fixed capital formation, FDI means the foreign direct investment, EU reflects the energy use, LogGDPPC is the log of gross domestic product per capita, PG represents the population growth, β , α and γ are the coefficients of explanatory variables in equations (1), (2) and (3), respectively.

The structural equation model is applied to three economic models when dealing with two mediations. The equation (1) investigates the direct effect of the explanatory variable (fintech) and mediating variables (financial inclusion and financial literacy) on the explained variable (green trade openness index) after including the gross fixed capital formation, foreign direct investment, energy use, gross domestic product per capita and population growth as control variables (Ghouse et al., 2025). While equation (2) explains the effect of fintech on financial inclusion. The combined effect of β_1 and α_1 determines the mediating position of financial inclusion while explaining the effect of fintech on green trade. Similarly, the equation (3) evaluates the effect of fintech on financial literacy. Hence, the combined effect of β_1 and γ_1 explains the mediating role of financial literacy.

3.2 Data and Sampling

This study collected a panel of country-level secondary data from 2010 to 2023. This study intends to investigate the post-financial crisis impact of fintech on the real economy, since the behavior of fintech has been positively molded in response to the financial crisis.

The data of green trade is collected from the UN Comtrade database⁵ (Can, Ben Jebli, et al., 2022). Can et al. (2022) developed a Green Trade Openness Index (GTOI) by employing the “Combined List of Environmental Goods (CLEG+)”, which consists of 40 core products identified by HS code. The CLEG+ has been developed by Sauvage (2014), who modified and condensed the combined list developed by OECD.⁶

The FinTech and financial inclusion data are retrieved from the Global Financial Inclusion database by the World Bank Databank. The Global Financial Inclusion database provides four data-year points within its panel: 2011, 2014, 2017, and 2021. We created two equal lead values in the subsequent two years against each annual data point to reduce the missing values. For 2020, we considered the average of 2017 and 2021 data points. However, we also deployed an alternate proxy (use of mobile) retrieved from World Development Indicators that provides annual continuous data, to confirm the robustness of our proxy. The remaining data are retrieved from World Development Indicators. All variables are defined in Table 1.

Table 1

Variables

Variable	Definition/Proxy	Source
Green Trade Innovation Index	Sum of Green Exports and Imports divided by the GDP multiplied with hundred	UN ComTrade
FinTech	People who made or received a digital payment among the total population (>15 Years %)	Global Financial Inclusion Database
Financial Inclusion	People who own account in a bank among the total population (>15 Years %)	Global Financial Inclusion Database
Financial Literacy	Broad Money to GDP ratio (%)	WDI



Variable	Definition/Proxy	Source
Gross Fixed Capital Formation	Gross Fixed Capital Formation to GDP ratio (%)	WDI
Foreign Direct Investment	Foreign Direct Investment to GDP ratio (%)	WDI
Energy Use	Energy use (kg of oil equivalent) per \$1,000 GDP (constant 2021 PPP)	WDI
Log GDP Per Capita	Log of Gross Domestic Product Per capita	WDI
Population Growth	Annual percentage change in Population	WDI

Note. WDI stands for World Development Indicators retrieved from World Bank Databank.

The initial data includes 3,869 panel observations, which also include regional data and data from 2010, which were excluded before analysis, along with all missing data. The actual analysis was conducted with the remaining data. The data was winsorized at the 1st and 99th percentiles to improve the normality in the final data.

4. Results and Discussion

4.1 Summary Statistics

Table 2 shows the descriptive statistics results. Results reveal that green trade is 52% of GDP on average, which reflects that green trade is one of the significant sources of global trade. The fintech average value shows that around 34% of the population is engaged in digital payments (financial technology). However, the standard deviation (34.904%) and the range from minimum (0%) to maximum (99.285%) values of fintech reflect that the use of fintech varies among the countries and across the time series. The financial inclusion data reflect that nearly half of the population (47%) is involved in formal banking. The financial literacy data (69.114) also show that countries are aware of financial knowledge.

Table 2

Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
GTOI	2217	50.547	36.560	6.658	206.118
FinTech	2576	33.580	34.904	0	99.285
Financial Inclusion	2576	47.513	34.797	0	99.790
Financial Literacy	2647	69.114	46.551	14.007	280.355
Gross Fixed Capital Formation	2955	23.517	6.951	7.981	46.966
Foreign Direct Investment	3368	5.279	12.586	-10.514	103.337
Energy Use	2472	100.313	50.965	31.423	336.206
Log GDP Per Capita	3576	8.746	1.395	6.034	11.564
Population Growth	3709	1.203	1.320	-2.517	4.833

Note. GTOI refers to the Green Trade Openness Index. FinTech means financial technology.

4.2 Empirical Results

4.2.1 Primary Results. Table 3 includes the primary results of our study where we studied the effect of fintech on green trade. In addition, we evaluated the mediating roles of financial inclusion and financial literacy in explaining the relationship between fintech and green trade. Results reveal in Panel A that the direct effect of fintech on green trade is insignificant ($\beta = -0.068$, $p > 0.1$), while the effect of financial inclusion ($\beta = 0.169$, $p < 0.01$) is positive and significant, and the effect of financial literacy ($\beta = -0.052$, $p < 0.05$) on green trade is negative and significant.

Though, Panel B shows that fintech positively and strongly affects the financial inclusion ($\alpha = 0.662$, $p < 0.01$). According to Sobel test in panel D, the mediating role of financial inclusion between fintech and green trade is positive, significant and complete ($\beta = 0.112$, $p < 0.01$). The RIT shows that the indirect effect of fintech through financial inclusion on green trade is 252.1% stronger in comparison to the total effect, and it is 165.7% stronger than the direct effect.



Results justify that the direct relationship between fintech and green trade is weak, while the mediation of financial inclusion is significant, strong, positive and complete while determining the relationship between fintech and green trade. Hence, financial inclusion significantly transforms the influence of fintech in improving the green trade. These results are in line with the existing literature, since the literature suggests that fintech improves green finance and green investments through financial inclusion (Ghouse et al., 2025; Kesavan & Polisetty, 2025). Resultantly, the investment in green business and green finance enhances the green trade (Can, Ben Jebli, et al., 2022; Can, Oluc, et al., 2022; Van Ledden et al., 2024).

These results are important from a policy perspective because sustainable development is a global target, while green trade is one of the significant sources of sustainable development. Hence, the role of financial inclusion in conjunction with financial technology is crucial in achieving the UN Sustainable Development Goals (Arner et al., 2020; Can, Ben Jebli, et al., 2022; Can, Oluc, et al., 2022; Danladi et al., 2023; Hunjra et al., 2023; Kishor et al., 2024).

Panel C of Table 3 reflects the effect of fintech on financial literacy. The results show that the effect of fintech on financial literacy is also positive and significant ($\gamma = 0.110$, $p < 0.05$). However, the Sobel test in Panel E reveals that the mediating role of financial literacy between fintech and green trade is weak ($\beta = 0.006$, $p > 0.1$). These results justify that financial literacy does not mediate the effect of fintech on green trade. Hence, fintech does not affect the green trade through financial literacy but through financial inclusion. The coefficients of control variables are consistent with the literature (Ghouse et al., 2025; Kesavan & Polisetty, 2025).

Table 3

SEM Analysis – Explained Variable: GTOI

	Coefficient	Standard Error
Panel A: Effect of FinTech, Financial Inclusion and Financial Literacy on GTOI		
Financial Inclusion	0.169***	0.064
Financial Literacy	-0.052**	0.025
FinTech	-0.068	0.063
Gross Fixed Capital Formation	0.962***	0.145
Foreign Direct Investment	1.775***	0.273
Energy Use	0.043***	0.016
Log GDP Per Capita	5.234***	0.850
Population Growth	-5.059***	0.906
Constant	-23.179***	8.079
Panel B: Effect of FinTech on Financial Inclusion		
FinTech	0.662***	0.025
Gross Fixed Capital Formation	0.203**	0.082
Foreign Direct Investment	0.042	0.083
Energy Use	0.006	0.015
Log GDP Per Capita	5.693***	0.770
Population Growth	-1.819***	0.501
Constant	-26.621***	6.360
Panel C: Effect of FinTech on Financial Literacy		
FinTech	0.110**	0.044
Gross Fixed Capital Formation	1.002***	0.252
Foreign Direct Investment	1.263***	0.478
Energy Use	-0.049***	0.017
Log GDP Per Capita	15.605***	0.988
Population Growth	-3.786***	1.134
Constant	-90.177***	9.768



	Coefficient	Standard Error
Observations	1199	
Panel D: Mediation Analysis – Mediating Variable: Financial Inclusion		
Sobel Test	0.112***	0.042
Mediation	Complete	
RIT	2.521	
RID	1.657	
Panel E: Mediation Analysis – Mediating Variable: Financial Literacy		
Sobel Test	−0.006	0.004
Mediation	Not Significant	
RIT	0.007	
RID	0.084	

Note. *** significant at 0.01. ** significant at 0.05. * significant at 0.1. SEM means structural equation modelling. GTOI refers to the Green Trade Openness Index. FinTech means financial technology. RIT refers to the ratio of indirect effect to total effect, RID means ratio of indirect effect to direct effect.

4.2.2 Extended Analysis

4.2.2.1 Classification of Fintech Through Gender. We extend our study to investigate the effect of gender-wise fintech usage on green trade while considering the mediating role of financial inclusion. In most of the developing and underdeveloped countries, males dominate the businesses, and women do not participate in business and trade activities. In such countries, women are even unable to access the fintech (Ghosh, 2022). Hence the mediating role of financial inclusion may be higher while male using fintech in contrast to female usage when determining the green trade.

Table 4 classifies the sample by gender, considering fintech usage. Columns 2 and 3 of Table 4 include the sample of male using fintech, while columns 4 and 5 are female-oriented fintech usage analysis. Results in Panel A show that neither male-oriented fintech usage nor female-oriented fintech usage explains the green trade. Panels B and C show that financial inclusion significantly improves the influence of fintech on green trade among male and female-oriented fintech usage countries. The higher Sobel coefficient of females ($\beta = 0.118$) and RIT (2.99) in comparison to male Sobel ($\beta = 0.103$) and RIT (2.169) reveals that in countries where female participation in fintech usage is higher, the mediating influence of financial inclusion, for improving the green trade, in response to fintech, is stronger. The findings imply that the expanding representation of women in managerial roles significantly amplifies the effectiveness of fintech services in promoting green trade, primarily through the mediating role of financial inclusion (Nasar et al., 2025).

Table 4

SEM Analysis – Explained Variable: GTOI – Classification by Gender in Using FinTech

	Male		Female	
	Coefficient	SE	Coefficient	SE
Panel A: Effect of FinTech and Financial Inclusion on GTOI				
Financial Inclusion	0.161**	0.063	0.176***	0.063
FinTech	−0.055	0.061	−0.079	0.063
Gross Fixed Capital Formation	0.963***	0.145	0.962***	0.145
Foreign Direct Investment	1.772***	0.273	1.779***	0.274
Energy Use	0.043***	0.016	0.043***	0.016
Log GDP Per Capita	5.179***	0.855	5.306***	0.849
Population Growth	−5.054***	0.909	−5.078***	0.903
Constant	−22.640***	8.121	−23.859***	8.062
Panel B: Effect of FinTech on Financial Inclusion				
FinTech	0.639***	0.024	0.671***	0.026
Gross Fixed Capital Formation	0.210**	0.082	0.195**	0.083



Foreign Direct Investment	0.066	0.084	0.016	0.082
Energy Use	0.009	0.015	0.004	0.015
Log GDP Per Capita	6.246***	0.748	5.315***	0.787
Population Growth	-1.937***	0.501	-1.657***	0.506
Constant	-32.392**	6.203	-21.944***	6.546
Observations	1199		1199	

Panel C: Mediation Analysis – Mediating Variable: Financial Inclusion

Sobel Test	0.103**	0.041	0.118***	0.042
Mediation	Complete		Complete	
RIT	2.169		2.990	
RID	1.855		1.503	

Note. *** significant at 0.01. ** significant at 0.05. * significant at 0.1. SEM means structural equation modelling. GTOI refers to the Green Trade Openness Index. FinTech means financial technology. RIT refers to the ratio of indirect effect to total effect, RID means ratio of indirect effect to direct effect.

4.2.2.2 Classification of Financial Inclusion. Table 5 reports the classification of financial inclusion in terms of gender, age, education and economic class. Columns 2 and 3 include the classification of financial inclusion according to gender. Results reveal that financial inclusion significantly improves the effect of fintech on green trade, irrespective of gender. Similar to the gender-wise classification of fintech, the Sobel coefficient ($\beta = 0.110$) and RIT (2.496) of females are higher than those of males (Sobel coefficient $\beta = 0.103$ and RIT (2.319), which confirms that the female participation in fintech and financial inclusion improves the role of financial inclusion in strengthening the effect of fintech on green trade.

We reported the classification of financial inclusion by age in columns 4 and 5 of Table 5. The mediation analysis in Panel C shows that financial inclusion among older people (25+ years) improves the positive effect of fintech on green trade, while the role of financial inclusion of young people (15+ to less than 25 years age) is weak. These results justify that young people do not participate in formal international trade; therefore, their participation in the formal financial system does not improve the green trade. While older people are directly engaged in official business, the more they engage in the financial sector, the more fintech helps improve the green trade. These results are in support of Demirgüç-Kunt et al. (2020), which claims that adults have higher access to formal financial services, while youth can access informal financial services. However, financially included and fintech-using young generation may improve the green trade in the future. Future studies may investigate this phenomenon, which is beyond the scope of the current study.

Columns 6 and 7 report the financial inclusion classification by education of people engaged in formal financial services. The mediation results in Panel C show that when formal financial services are utilized by people with secondary education, financial inclusion significantly enhances the effect of fintech on green trade, while this relationship is weak when the qualification of people engaged in financial inclusion is primary. These results show that higher qualifications enhance the capability and intellect of people in utilizing the fintech and formal financial services for green trade (Allen et al., 2016).

Columns 8 and 9 classify the financial inclusion according to economic class. Results reveal that financial inclusion does not influence the effect of fintech on green trade when we distribute the sample between the rich and the poor. These results suggest that financial inclusion plays a mediating position between fintech and green trade, irrespective of the economic agent's income level. When the aggregate of rich and poor economic classes engages in formal banking services, their collective efforts in utilizing the fintech improve the green trade (Allen et al., 2016; Demirgüç-Kunt et al., 2020).

Table 5

SEM Analysis – Explained Variable: GTOI – Classification of Financial Inclusion Proxy

Gender		Age		Education		Economic Class	
Male	Female	Young	Older	Secondary	Primary	Rich	Poor
Panel A: Effect of FinTech and Financial Inclusion on GTOI							



FI	0.156*** (0.058)	0.167** (0.066)	0.047 (0.072)	0.170*** (0.060)	0.145*** (0.056)	0.003 (0.071)	0.029 (0.056)	0.082 (0.069)
FT	-0.059 (0.059)	-0.066 (0.065)	0.013 (0.068)	-0.069 (0.060)	-0.055 (0.059)	0.042 (0.064)	0.023 (0.057)	-0.013 (0.064)
GFCF	0.964*** (0.145)	0.962*** (0.145)	0.976*** (0.145)	0.966*** (0.145)	0.934*** (0.146)	0.987*** (0.144)	0.982*** (0.144)	0.974*** (0.144)
FDI	1.784*** (0.276)	1.764*** (0.271)	1.774*** (0.275)	1.774*** (0.273)	1.772*** (0.273)	1.770*** (0.275)	1.777*** (0.276)	1.785*** (0.277)
EU	0.043*** (0.016)	0.043*** (0.016)	0.043*** (0.016)	0.043*** (0.016)	0.044*** (0.016)	0.044*** (0.016)	0.045*** (0.016)	0.043*** (0.016)
LGDP PC	5.388*** (0.847)	5.171*** (0.849)	5.824*** (0.858)	5.261*** (0.849)	5.760*** (0.836)	6.038*** (0.891)	5.968*** (0.875)	5.610*** (0.942)
PG	-5.156** *	-4.959** *	-5.296** *	-5.102** *	-5.088** *	-5.335** *	-5.273** *	-5.212** *
C	(0.906) -24.541* **	(0.914) -22.307* **	(0.928) -25.306* **	(0.905) -23.965* **	(0.903) -27.528* **	(0.937) -26.743* **	(0.901) -26.900* **	(0.901) -23.961* **
	(8.063)	(8.079)	(8.145)	(8.065)	(8.080)	(8.447)	(8.107)	(8.689)

Panel B: Effect of FinTech on Financial Inclusion

FT	0.663*** (0.026)	0.661*** (0.025)	0.640*** (0.024)	0.664*** (0.026)	0.684*** (0.027)	0.601*** (0.024)	0.708*** (0.026)	0.692*** (0.023)
GFCF	0.209** (0.088)	0.197** (0.080)	0.288*** (0.083)	0.174** (0.086)	0.413*** (0.098)	0.179** (0.080)	0.213** (0.091)	0.203*** (0.075)
FDI	-0.011 (0.081)	0.095 (0.087)	0.009 (0.080)	0.040 (0.085)	0.053 (0.088)	0.065 (0.086)	-0.204** (0.074)	-0.122** (0.062)
EU	0.004 (0.016)	0.007 (0.014)	0.014 (0.014)	0.003 (0.015)	-0.002 (0.015)	-0.002 (0.013)	-0.017 (0.013)	0.011 (0.012)
LGDP PC	5.264*** (0.805)	6.000*** (0.749)	5.917*** (0.730)	5.447*** (0.790)	2.842*** (0.791)	6.506*** (0.746)	3.420*** (0.762)	6.123*** (0.719)
PG	-1.369** (0.563)	-2.407** (0.470)	-1.031** (0.473)	-1.547** (0.527)	-1.881** (0.556)	0.375 (0.492)	-2.188** (0.542)	-1.636** (0.468)
C	-20.533* **	-31.328* **	-38.772* **	-21.544* **	-0.074 **	-43.205* **	-0.841** *	-39.346* **
	(6.763)	(6.125)	(6.114)	(6.561)	(6.643)	(6.086)	(6.334)	(5.717)
N	1199	1199	1199	1199	1199	1199	1199	1199

Panel C: Mediation Analysis – Mediating Variable: Financial Inclusion

ST	0.103*** (0.039)	0.110** (0.044)	0.030 (0.046)	0.113*** (0.040)	0.099*** (0.038)	0.002 (0.042)	0.020 (0.040)	0.057 (0.048)
M	Complete	Complete	Insignific ant	Complete	Complete	Insignific ant	Insignific ant	Insignific ant
RIT	2.319	2.496	0.693	2.551	2.246	0.044	0.466	1.292
RID	1.758	1.668	2.255	1.645	1.803	0.045	0.874	4.428

Note. *** significant at 0.01. ** significant at 0.05. * significant at 0.1. Standard error in parentheses. SEM means structural equation modelling. GTOI refers to the Green Trade Openness Index. FI represents the Financial Inclusion, FT means financial technology, GFCF refers to gross fixed capital formation, FDI is the



foreign direct investment, EU is the energy use, LGDPPC is the log gross domestic product per capita, PG is the population growth, C represents the constant, N means numbers of observations, M is the symbol of mediation, RIT refers to the ratio of indirect effect to total effect, RID means ratio of indirect effect to direct effect.

4.2.2.3 Analysis of Green Exports, Green Imports and Net Green Exports. In addition to the Green Trade Innovation Index (GTOL), we considered three alternate proxies for green trade, including green exports, green imports and net green exports, to understand how green trade is influenced through financial inclusion and fintech. Table 6 reports the results. Results demonstrate that the mediating contribution of financial inclusion in determining the effect of fintech on green exports and net green exports in Panel C of columns 2 and 5 are positive, significant and complete, while the effect is insignificant in column 3 for net imports. These results suggest that fintech improves access to financing for green exports more than green imports. Higher access to financial services through fintech enables the SMEs and small businesses to enhance the green exports, while imports are normally controlled by big firms, hence they do not change because of the improvement in fintech or access to finance. Results also suggest that fintech and financial inclusion have been more beneficial for green exporting countries than for green importing countries.

Table 6

SEM Analysis – Explained Variable: Green Export, Green Import, Net Green Export

	Green Export		Green Import		Net Green Export	
	Coefficient	St. Error	Coefficient	St. Error	Coefficient	St. Error
Panel A: Effect of FinTech and Financial Inclusion on Green Export, Green Import and Net Green Export						
Financial Inclusion	0.002***	0.000	−0.000	0.000	0.002***	0.000
FinTech	0.000	0.000	0.000	0.000	0.000	0.000
Gross Fixed Capital Formation	0.004***	0.001	0.008***	0.001	−0.005***	0.001
Foreign Direct Investment	0.000	0.000	0.001***	0.000	−0.001***	0.000
Energy Use	−0.000***	0.000	0.000***	0.000	−0.001***	0.000
Log GDP Per Capita	0.020*	0.011	0.003	0.004	0.018	0.011
Population Growth	−0.063***	0.013	−0.026***	0.005	−0.034***	0.012
Constant	−0.056	0.114	0.121***	0.045	−0.182*	0.110
Panel B: Effect of FinTech on Financial Inclusion						
FinTech	0.581***	0.023	0.581***	0.023	0.581***	0.023
Gross Fixed Capital Formation	0.040	0.077	0.042	0.077	0.040	0.077
Foreign Direct Investment	0.081*	0.049	0.080*	0.049	0.081*	0.049
Energy Use	0.001	0.014	0.000	0.014	0.001	0.014
Log GDP Per Capita	6.977***	0.689	6.962***	0.687	6.977***	0.689
Population Growth	−2.433***	0.458	−2.401***	0.453	−2.433***	0.458
Constant	−29.203***	5.793	−29.062***	5.779	−29.203***	5.793
Observations	1564		1572		1564	
Panel C: Mediation Analysis – Mediating Variable: Financial Inclusion						
Sobel Test	0.001***		0.000		0.001***	
Mediation	Complete		Insignificant		Complete	
RIT	0.828		1.512		0.868	



RID	4.816	2.951	6.590
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Note. *** significant at 0.01. ** significant at 0.05. * significant at 0.1. SEM means structural equation modelling. RIT refers to the ratio of indirect effect to total effect, RID means ratio of indirect effect to direct effect.

4.2.2.4 Moderation to Mediation Analysis

4.2.2.4.1 Classification of Sample According to Urban Population Ratio. In Table 7, we reported the mediation analysis by extending our investigation in three categories: according to urban population ratio, population growth and level of income. In columns 2 and 3, we evaluated the mediation of financial inclusion while studying the effect of fintech on green trade after distributing our sample into high and low urban population subgroups, respectively. We considered the top/bottom three deciles of urban population as the high/low urban population groups. The Sobel test in Panel C reports that financial inclusion does not significantly influence the relationship between fintech and green trade in highly urbanized countries. However, the mediating role of financial inclusion is negative and significant in low urban population observations (Allen et al., 2016; Demirgüç-Kunt et al., 2020).

These results suggest that the concentration of financial access only to urban population would not help fintech in promoting the green trade, while financial inclusion negatively deviates the effect of fintech on green trade, when access to finance is concentrated among the rural population. The higher tendency of financial inclusion towards the rural population compared to the urban population deviates the influence of fintech from green export/import to local agriculture development, hence negatively affecting the green trade. These results are in support of Allen et al. (2016) and Ozili (2018), who claim that the marginal impact of financial inclusion in rural areas is higher than in urban areas. Hence, the deviation of financial inclusion and fintech towards agriculture development from green trade will be higher when access to finance is higher in rural areas.

4.2.2.4.2 Classification of Sample According to Population Growth. We redistributed the sample into high and low population growth by considering the top and bottom three deciles, respectively, in the fourth and fifth columns of Table 7. Results in Panel C suggest that financial inclusion is unable to mitigate the effect of fintech on green trade when population growth is high, while its effect is positive and significant with low population growth. Fintech-led financial inclusion can't facilitate the fast-growing population in improving the green trade, while in countries with low population growth, fintech infrastructure easily enhances financial inclusion in promoting the green trade (Demirgüç-Kunt et al., 2020; O'Neill et al., 2018; Ozili, 2018; York et al., 2003).

4.2.2.4.3 Classification of Samples According to Countries' Level of Income. Columns 6 and 7 of Table 7 report the high- and low-income countries. The high-income countries include the top three deciles of GDP per capita, while the bottom three deciles include the low-income countries. The Sobel test coefficient in high-income countries is positive and significant, while it is negative and significant in low-income countries. These results advocate that when fintech and financial inclusion are high among high-income countries, green trade increases. However, the high financial inclusion concentration in low-income countries discourages the green trade. In high-income countries, the fintech environment and awareness regarding financial services motivate the green trade because of higher potential for exports; however, in low-income countries, they utilize fintech in other private means, like consumption, instead of green trade, which leads to the reduction of green trade (Ozili, 2018).

Table 7

SEM Analysis – Explained Variable: GTOI – Moderation in Mediation Analysis

	Urban Population Ratio		Population Growth		Income	
	High	Low	High	Low	High	Low
Panel A: Effect of FinTech and Financial Inclusion on GTOI						
Financial Inclusion	0.110 (0.073)	-0.302*** (0.073)	0.222 (0.142)	0.605*** (0.121)	0.169* (0.087)	-0.295*** (0.094)



FinTech	−0.029 (0.064)	0.127* (0.069)	−0.371*** (0.138)	−0.083 (0.117)	−0.098 (0.086)	0.149* (0.090)
Gross Fixed Capital Formation	2.704*** (0.339)	0.945*** (0.193)	1.208*** (0.194)	1.899*** (0.423)	4.109*** (0.698)	0.785*** (0.155)
Foreign Direct Investment	3.398*** (0.384)	2.315*** (0.667)	1.344*** (0.271)	1.064*** (0.329)	2.027*** (0.629)	1.544*** (0.248)
Energy Use	0.063** (0.028)	0.046 (0.035)	−0.037* (0.021)	0.063** (0.031)	0.015 (0.031)	0.058** (0.027)
Log GDP Per Capita	2.665 (2.239)	7.424** (2.933)	6.975*** (1.429)	10.760*** (2.852)	−13.124** (5.940)	10.079*** (3.305)
Population Growth	0.896 (1.118)	−2.153** (1.010)	1.070 (2.199)	−14.390*** (3.663)	−6.684*** (1.771)	−3.024*** (1.126)
Constant	−56.969*** (21.319)	−45.849** (23.342)	−44.924*** (8.580)	−92.083*** (25.981)	107.508* (64.664)	−57.290** (26.991)

Panel B: Effect of FinTech on Financial Inclusion

FinTech	0.523*** (0.050)	0.826*** (0.044)	0.811*** (0.037)	0.566*** (0.049)	0.508*** (0.059)	0.857*** (0.024)
Gross Fixed Capital Formation	0.209 (0.299)	0.453*** (0.100)	−0.057 (0.115)	0.234 (0.196)	−0.074 (0.525)	0.263*** (0.084)
Foreign Direct Investment	0.065 (0.161)	−1.419*** (0.248)	0.560** (0.271)	−0.081 (0.078)	0.034 (0.103)	−0.280*** (0.104)
Energy Use	−0.119*** (0.028)	0.020 (0.018)	0.013 (0.016)	−0.057** (0.027)	−0.096*** (0.028)	0.021 (0.014)
Log GDP Per Capita	10.518*** (1.952)	6.280*** (2.430)	4.913*** (1.139)	6.818*** (1.792)	1.586 (3.249)	0.923 (1.360)
Population Growth	0.423 (1.044)	−2.021** (0.922)	0.780 (1.680)	−0.501 (1.561)	0.399 (1.393)	−3.815*** (0.731)
Constant	−60.429*** (16.150)	−35.482* (18.692)	−27.446*** (8.912)	−25.593* (14.566)	39.466 (35.060)	5.873 (10.710)
Observations	380	265	335	340	258	344

Panel C: Mediation Analysis – Mediating Variable: Financial Inclusion

Sobel Test	0.058 (0.038)	−0.249*** (0.062)	0.180 (0.116)	0.343*** (0.075)	0.086* (0.046)	−0.253*** (0.081)
Mediation	Insignificant	Complete	Insignificant	Complete	Weak	Complete
RIT	2.033	2.037	0.940	1.318	7.265	2.435
RID	1.968	1.965	0.485	4.140	0.879	1.697

Note. *** significant at 0.01. ** significant at 0.05. * significant at 0.1. Standard error in parentheses. SEM means structural equation modelling. RIT refers to the ratio of indirect effect to total effect, RID means ratio of indirect effect to direct effect.

4.3 Robustness Tests

In addition to our primary and extended results, we considered alternative proxies and econometrics techniques to test the robustness of our results. In Table 8, we replaced the proxy of fintech with two alternate proxies: usage of mobile money (columns 2 and 3), which is another significant method of fintech usage, and use of mobile (columns 4 and 5), which is a broader proxy of technology usage.⁷ The Sobel test results of both



proxies confirm the primary results that financial inclusion significantly improves the effect of fintech on green trade.

Table 8

SEM Analysis – Explained Variable: GTOI – Alternate Proxies of FinTech

	Mobile Money		Use of Mobile	
	Coefficient	SE	Coefficient	SE
Panel A: Effect of FinTech and Financial Inclusion on GTOI				
Financial Inclusion	0.171***	0.042	0.109***	0.037
FinTech	-0.300***	0.066	0.090***	0.035
Gross Fixed Capital Formation	0.913***	0.141	0.973***	0.142
Foreign Direct Investment	1.772***	0.279	1.695***	0.271
Energy Use	0.046***	0.016	0.048***	0.016
Log GDP Per Capita	3.879***	0.961	4.207***	0.936
Population Growth	-4.403***	0.884	-4.816***	0.952
Constant	-11.772	8.821	-24.548***	8.131
Panel B: Effect of FinTech on Financial Inclusion				
FinTech	0.969***	0.032	0.095***	0.027
Gross Fixed Capital Formation	0.338***	0.108	0.187	0.125
Foreign Direct Investment	0.123	0.098	0.056	0.110
Energy Use	-0.023	0.023	-0.019	0.023
Log GDP Per Capita	14.692***	0.764	10.850***	0.961
Population Growth	-4.779***	0.645	-2.672***	0.675
Constant	-84.636***	7.836	-56.484***	8.358
Observations	1199		1169	
Panel C: Mediation Analysis – Mediating Variable: Financial Inclusion				
Sobel Test	0.166***	0.041	0.010***	0.005
Mediation	Partial		Partial	
RIT	1.229		0.104	
RID	0.551		0.116	

Note. *** significant at 0.01. ** significant at 0.05. * significant at 0.1. SEM means structural equation modelling. RIT refers to the ratio of indirect effect to total effect, RID means ratio of indirect effect to direct effect.

Table 9 reports the commercial bank borrowers as the alternate proxy of financial inclusion to test the robustness of the financial inclusion proxy. The Sobel test results suggest that our alternate proxy results complement our primary results and show that the mediating effect of financial inclusion is significant while investigating the effect of fintech on green trade.

Table 9

SEM Analysis – Explained Variable: GTOI – Alternate Proxy of Financial Inclusion

	Coefficient	Standard Error
Panel A: Effect of FinTech and Financial Inclusion on GTOI		
Financial Inclusion	0.041***	0.012
FinTech	0.075	0.061
Gross Fixed Capital Formation	0.756***	0.187
Foreign Direct Investment	1.299***	0.291
Energy Use	0.107***	0.026
Log GDP Per Capita	4.998***	1.451
Population Growth	-5.075***	1.291
Constant	-27.588***	12.580



Panel B: Effect of FinTech on Financial Inclusion

FinTech	1.593***	0.266
Gross Fixed Capital Formation	1.514*	0.815
Foreign Direct Investment	3.575**	1.797
Energy Use	0.059	0.150
Log GDP Per Capita	116.180***	10.427
Population Growth	-22.660**	5.104
Constant	-812.134***	93.705
Observations	654	

Panel C: Mediation Analysis – Mediating Variable: Financial Inclusion

Sobel Test	0.065***	0.022
Mediation	Complete	
RIT	0.463	
RID	0.863	

Note. *** significant at 0.01. ** significant at 0.05. * significant at 0.1. SEM means structural equation modelling. RIT refers to the ratio of indirect effect to total effect, RID means ratio of indirect effect to direct effect.

In Table 10, we presented the results of causal mediation analysis, an alternative econometric technique for investigating the causal mediating relationships (Imai et al., 2010). The third panel of Table 10 shows that the indirect effect (NIE) of fintech on green trade through financial inclusion is significant and positive ($\beta = 0.074$, $p < 0.01$). These results are consistent with our main results that financial inclusion has a significant mediating influence on the relationship between fintech and green trade.⁸

Table 10

Causal Mediation Analysis – Explained Variable: GTOI

	Coefficient	Standard Error
Panel A: Effect of FinTech and Financial Inclusion on GTOI		
FinTech	-0.378***	0.115
Financial Inclusion	0.125***	0.044
FinTech x Financial Inclusion	0.004***	0.001
Gross Fixed Capital Formation	1.132***	0.152
Foreign Direct Investment	0.153**	0.069
Energy Use	0.022	0.019
Log GDP Per Capita	3.210***	0.935
Population Growth	-6.511***	0.752
Constant	-1.755	9.499
F Statistics	39.92***	
R ²	0.17	
Adjusted R ²	0.17	
Observations	1564	
Panel B: Effect of FinTech on Financial Inclusion		
FinTech	0.570***	0.014
Gross Fixed Capital Formation	0.176**	0.071
Foreign Direct Investment	0.078**	0.038
Energy Use	-0.013	0.009
Log GDP Per Capita	7.058***	0.398
Population Growth	-2.615***	0.390
Constant	-30.895***	4.167
F Statistics	709.54***	



	Coefficient	Standard Error
R ²	0.68	
Adjusted R ²	0.68	
Observations	2013	
Panel C: Mediation Analysis – Mediating Variable: Financial Inclusion		
CDE	−0.373***	0.114
NDE	−0.242***	0.080
NIE	0.074***	0.025
MTE	−0.168**	0.075

Note. *** significant at 0.01. ** significant at 0.05. * significant at 0.1. CDE, NDE, NIE and MTE are controlled direct effect, natural direct effect, Natural Indirect effect and Marginal total effect, respectively.

5. Conclusion

This study investigates the effect of financial technology on the green trade. In addition, we evaluate the mediating role of financial inclusion and financial literacy in explaining the effect of fintech on green trade. The results suggest that fintech does not directly affect the green trade. Moreover, financial literacy does not mediate this relationship. Financial inclusion significantly improves the effect of fintech on green trade.

The extended analysis reports that the mediating role of financial inclusion in explaining the effect of fintech on green trade is stronger when the working group and the secondary educated population have access to finance. Results are also significant and positive when financial inclusion mediates the effect of fintech on green export and net green export. The mediating role of financial inclusion between fintech and green trade is significantly positive in countries with low population growth and among high-income countries. Yet this relationship is similar among male and female populations using fintech or having access to finance. Results are robust to alternative proxies of fintech and financial inclusion. Results are also robust to alternative econometric estimators.

However, the extended results show that financial inclusion does not mediate the effect of fintech on green trade when considering the young population and the primary education population having access to finance. The relationship is also weak when classifying the financial inclusion across the economic classes. The relationship is also weak among high urban populations and high population growth. While it is negative and significant among high rural populations and among low-income countries. Financial inclusion does not mediate the effect of fintech on green imports as well.

Our results are valuable for country-level policies as well as for the global agenda of sustainable development. Our results provide some significant contributions towards strategic decisions for sustainable development. Based on our results, we suggest that countries should realign their three distinct policies: i) fintech infrastructure, ii) access to finance, and iii) green economy in one larger framework. Our results claim that fintech infrastructure improves access to finance, and financial inclusion results in an increase in green trade, which paves the path for the green economy. Global organizations may focus more on strengthening the policies that align with fintech, financial inclusion, and green trade.

Future researchers may extend our results in explaining the role of green finance and green investment in our framework. The study may also be extended for the analysis of climate change.

Ethics Statement

This study adhered to all ethical standards of research during the conducting of this study. We collected data from secondary sources, and no human participants were involved in the collection of data. Therefore, there is no conflict of interest of any human participant to this study.

Author's Contributions

All authors participated in ideation, development, and writing the manuscript. All authors read and approved the final manuscript.

Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding the publication of this article.



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Informed Consent

Informed consent was obtained from all participants prior to data collection. Participants were informed about the purpose of the study, the voluntary nature of their participation, and their right to withdraw at any time without any consequences. The confidentiality and anonymity of respondents were guaranteed throughout the research process.

Data Availability

The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request. The authors are committed to transparency and will provide detailed methodological information and analysis protocols upon request.

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