Does Fintech Adoption Improve Sustainable Supply Chain Management? An Innovation-Intensive Environment Perspective

***Abstract*—**Financial technology, or fintech, is used to describe disruptive new technologies that help firms manage their financial operations and improve the cost effectiveness of customer services. However, the role of fintech adoption in sustainable supply chain management performance is unclear. Using panel data from Chinese A-share listed companies from 2018 to 2022, we empirically demonstrate that fintech adoption can significantly improve sustainable supply chain management performance. This improvement is primarily attributed to fintech's ability to enhance information transparency and refine decision-making capabilities, thereby fostering sustainability. Furthermore, green innovation, digital innovation policies, top management team forward-looking innovation orientation, and persistent innovation orientation strengthen the relationship between fintech adoption and sustainable supply chain management performance. Green innovation enables firms to comply with environmental regulations and gain a competitive advantage, thereby facilitating the integration of fintech into sustainable supply chain management. Digital innovation policies provide regulatory support and establish norms, creating a conducive environment for technology applications. The innovation orientation of the top management team drives the continuous optimization of supply chain processes and services through fintech. This research contributes to the current industrial sustainability debate by integrating fintech adoption and sustainable supply chain management from an innovation-intensive environment perspective.

***Index Terms*—**Fintech; sustainable supply chain management; green innovation; digital innovation policy; top management team innovation orientation.

***Managerial Relevance Statement*—**Engineering managers can realize significant benefits from our research findings. Through the adoption of fintech, they can capitalize on technological advancements to revolutionize supply chain operations. This empowers them to make data-driven decisions swiftly, resulting in highly accurate demand forecasting, efficient inventory management, and strengthened supplier collaboration. For policymakers, it is crucial to formulate and implement policies that actively promote fintech adoption and support environmental innovation. They can provide targeted incentives for firms to invest in environmental innovation. A notable finding is the differential impact of fintech across firm ownership structures, with non-state-owned enterprises showing a particularly strong propensity for fintech adoption. Stakeholders can leverage the findings to improve the emerging technology adoption and the industrial sustainable practice by cultivating an innovation-intensive environment. Concrete action plans include fostering innovation-oriented corporate cultures and developing comprehensive regulatory frameworks to facilitate the effective integration of fintech into supply chain management, thereby advancing economic and environmental sustainability.

1. Introduction

Emerging technological innovation is driving rapid economic transformation and industry growth [21], [29], [50]. Financial technology (or "fintech") integrates several technologies, such as artificial intelligence (AI), blockchain, cloud computing, and big data, to improve the delivery of financial services [25], [34]. From 2020 to 2021, global investments in fintech increased by 147% to reach $210 billion, with $27.5 billion from the Asia–Pacific region and

$2.63 billion from China [61]. The Chinese government has recently published its *FinTech Development Plan (2022-2025)*, which aims to promote fintech adoption in the country [87].

Fintech is transforming the financial services sector by improving customer service, reducing firms' capital and operational costs [39], and better matching investors with investments [88]. It can be used for a range of financial services, including deposits, online payments, credit, insurance, digital currencies, capital raising, and investments [22], [122]. Blockchain technology, for example, can simplify complex financial transactions between multiple parties [4], [35]. Early fintech adopters such as Amazon and Ant Financial of Alibaba have become some of the world's largest lenders to small and medium-sized enterprises [113].

While previous researchers have focused on fintech adoption in terms of financial services [58], technological applications [124], and risk management [18], there is a growing emphasis on the relationship between fintech adoption and sustainability. For example, the United Nations [113] has identified fintech as a key factor in achieving its Sustainable Development Goals. Exploratory research has shown that fintech adoption can improve firms' resource allocation and sustainability [2], help small and medium-sized enterprises create circular business models [88], and enhance banks' environmental performance [108]. However, quantitative research on the relationship between fintech adoption and sustainability is lacking.

Innovation-intensive environments (IIEs) are specialized environments that accelerate the development and diffusion of advanced technologies [93]. For example, collaborations between firms, researchers, and policymakers can promote investments into green technologies [30]. Government innovation policies facilitate the uptake of digital technologies such as AI, blockchain, and the Internet of Things [14], improving supply chain transparency and resilience

[24], [37], [43] and firms' economic and environmental performance [76], [119]. Top management teams in IIEs have access to a wide range of up-to-date information, enabling them to make informed innovation decisions [11]. Moreover, high levels of innovative activity and a strong supportive ecosystem in IIEs support persistent innovation orientation [109], which is crucial for firms to adapt to market changes [79]. Therefore, we focus on the moderating effect of IIE characteristics (green innovation, digital innovation policies, top management team forward-looking innovation orientation, and persistent innovation orientation) on the relationship between fintech adoption and sustainable supply chain management (SSCM) performance.

Amid the growing demand for sustainable development is the use of fintech for SSCM [94]. Despite previous studies on the role of fintech in sustainability [47], [120], the effect of IIE characteristics on the relationship between fintech adoption and SSCM performance remains unclear. In the face of new environmental legislation, a growing customer demand for eco-friendly products and services [12], and the increasing stakeholder focus on firms' environmental and social performance [115], supply chain sustainability has become critical [53], [54], [55], [98]. Therefore, we aim to answer the following research questions, which consider the potential of both fintech adoption and the innovation environment in driving SSCM performance:

RQ1: *Does fintech adoption improve firms' SSCM performance?*

RQ2: *Do IIE characteristics (e.g., green innovation, digital innovation policies, top management team forward-looking innovation orientation, and top management team*

persistent innovation orientation) moderate the relationship between fintech adoption and SSCM performance?

This study makes two main contributions to the innovation and technology management literature. First, it demonstrates that fintech adoption has a positive effect on SSCM *performance*, helping to resolve previous mixed findings. Second, it applies the IIE perspective to technology adoption and SSCM performance by shedding light on the moderating role of IIE characteristics in the fintech–SSCM relationship. The findings offer insights for managers and policymakers in a rapidly changing economy.

This paper is structured as follows. First, we review the literature, then develop our hypotheses. Next, we present our methodology, data collection, and results. The paper concludes with a discussion of the findings, theoretical and managerial implications, limitations and future research directions.

2. Literature review

Fintech refers to technologies (e.g., AI, big data, and blockchain) that improve the delivery and use of financial services, promoting sustainable economic development and efficient resource utilization [122], [125]. Financial services can be digitized through low-cost digital platforms by fintech, enabling even small and micro companies to employ them via mobile devices [73], [92], [122]. In emerging economies, fintech adoption can enhance the transparency, diversity, decentralization, accessibility, and efficiency of financial services [78] and mitigate financial instability [122].

2.1. Innovation-intensive environments

IIEs can bring both economic and competitive advantages to firms [90], [93]. Firms may benefit from successful innovations through increased returns and lock-in advantages [82] and can become industry leaders by developing new innovations based on accumulated knowledge [17].

Certain IIE characteristics can accelerate the rate of commercially successful innovations [93]. First, *green innovations* can promote the sustainability of not only individual firms but entire supply chains and industries [23]. Second, governments can create *digital innovation policies* to encourage the uptake of technologies through the provision of financial support to firms and research institutions [83]. Rewarding highly innovative firms in emerging economies may accelerate the development of new products [105]. Third, top management team forward-looking innovation orientation can better identify innovation opportunities and gain a competitive edge [45]. Fourth, persistent innovation can ensure firm stability in uncertain environments [68]. While a company may not profit from a single innovation, it can leverage its capabilities and resources to continuously innovate [93]. Collectively, green innovation, digital innovation policies, top management team forward-looking innovation orientation, and top management team persistent innovation orientation create an environment that supports new technologies and business models and promotes the innovative capacity and competitiveness of the economy, contributing to economic, social, and environmental sustainability [1].

3. Hypothesis development

3.1. Fintech adoption and sustainable supply chain management performance

Fintech has transformed the way in which financial transactions take place [15], [122] and is leading the transition to SSCM [9], [88]. SSCM involves firms being environmentally and socially responsible in their SCM [69], [110], [114], which has become increasingly important in the face of rising customer expectations, government regulations, competitive pressures, and resource scarcity [40], [111]. Previous research has mostly focused on fintech from a technological perspective [56], [99], [100], including its use in online payments and banking and peer-to-peer lending [27], [77], [106]. However, few studies have explored the effect of fintech adoption on firms' sustainability performance, particularly in the context of SCM. Fintech adoption improves the efficiency of capital management and reduces the cost of financial services, thereby promoting SSCM [103]. Therefore, we propose the following:

H1. *Fintech adoption positively influences SSCM performance*.

3.2. Moderating effect of green innovation

Green innovation is critical for reducing resource consumption and achieving environmental sustainability [49], [51], [62], [72]. It helps firms comply with environmental regulations and mitigate their environmental impacts, promoting SSCM [16], [64], [91], [97], [118]. Firms that invest in green innovations may be more inclined to adopt fintech to improve their sustainability and gain a competitive advantage. Creating a financial environment that is conducive to innovation [51] is critical for SSCM. Therefore, we argue that green innovations may strengthen the positive effect of fintech adoption on SSCM performance:

H2. *Green innovation positively moderates the relationship between fintech adoption and SSCM performance.*

3.3. Moderating effect of digital innovation policies

Innovations are urgently needed to address global challenges related to poverty, the environment, health, education, food and water security, and affordable clean energy [84], [112]. Digital innovation policies promote the update of digital innovations by supporting innovative firms and individuals [109], leading to a radical transformation of products and services [80]. According to Planes-Satorra and Paunov [89], cumbersome regulations can hinder digital innovations. Therefore, digital innovation policies are crucial [83] and may create a more conducive environment for the adoption of technological solutions such as fintech for SSCM. Therefore, we argue that digital innovation policies may encourage firms to adopt fintech to improve their sustainability:

H3. *Digital innovation policies positively moderate the relationship between fintech adoption and SSCM performance.*

3.4. Moderating effect of the top management team innovation orientation

Firm sustainability and survival largely depend on management decisions [19], [44]. Forward-looking innovation orientation of top management team encourages innovative thinking and the development of new products, particularly in response to market changes [81], [121]. This is beneficial to boosting firm competitiveness and performance [60], [95], [101]. A forward-looking innovation orientation management team can facilitate the adoption of fintech [117], which in turn improves competitive advantage and sustainable development [108]. Thus, we propose the following hypothesis:

H4a. *The forward-looking innovation orientation of top management team positively affects the relationship between Fintech adoption and SSCM performance.*

Being persistently innovative allows managers to identify and interpret new information and market trends, engage in strategic decision-making, and leverage opportunities for innovation [46], [68]. The top management team creates an environment where fintech can be seamlessly integrated into SSCM practices [26]. The persistent innovation orientation of top management team also enables fintech to continuously improve products, services, and processes [39], thereby enhancing firms' SSCM performance. Therefore, we propose that:

H4b. *The persistent innovation orientation of top management team positively affects the relationship between Fintech adoption and SSCM performance.*

Fig. 1 illustrates the overall research framework.

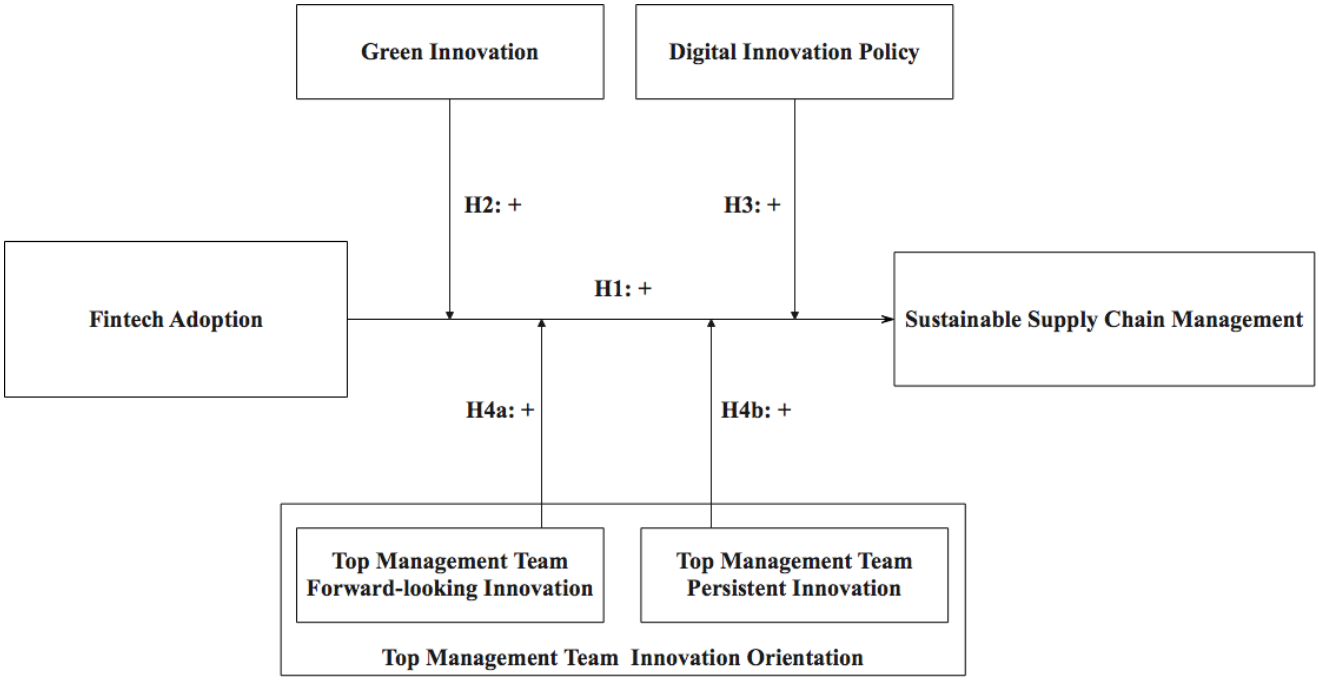

Fig. 1. Research framework.

4. Methodology

4.1. Data collection

Our sample includes Chinese A-share listed firms from 2018 to 2022. We collect basic and financial data from the Wind, China Stock Market & Accounting Research (CSMAR), and Green Patent Research Database (GPRD) of Chinese Research Data Services Platform (CNRDS), fintech adoption data from Tianyancha, and SSCM data from Bloomberg. To improve the accuracy of our results, we exclude financial institutions (e.g., banks and insurance firms) because of their unique asset and liability functions, firms with abnormal financial performance (i.e., Special Treatment firms), and observations with missing data on key variables [54]. The final sample comprises 4,038 observations from 935 firms. Table 1 presents our data categories and variable definitions.

Table 1. Variable description

Variable	Operationalization	Data Source	References
Sustainable supply chain management performance	Bloomberg ESG disclosure scores	Bloomberg	Gualandris et al., 2021; Kim & Davis, 2016; Wang & Sarkis, 2013
Fintech adoption	The log transformation of 1+the number of FinTech companies at prefecture-level city	Tianyancha website	Dong & Yu, 2023; He et al., 2023
Green innovation	The total number of green patent applications (including independently applied and jointly applied with other firms)	CNRDS	Cumming et al., 2020; Guan et al., 2021
Digital innovation policy	The total number of digital innovation standards development participation (including national and industry digital innovation standards)	CSMAR	Li et al., 2018; Teece, 2018
Top management team forward-looking innovation	Difference between the year in which the digital transformation feature first appeared in the MD&A section of the annual report and the current year	CSMAR	Jissink et al., 2019; Yadav et al., 2007

orientation	(current year - year of first appearance), or 0 if it did not occur		
Top management team persistent innovation orientation	Total number of years in which digital transformation featured in the MD&A section of the annual report as of that year	CSMAR	Denicolai & Previtali, 2023; Latan et al., 2020
Firm size	The log of the total sales	WIND	Chen et al., 2023
Firm profitability	Return on assets (ROA)	WIND	Jacobs & Singhal, 2020
Firm leverage	Total debt divided by total assets (LEV)	WIND	Jacobs & Singhal, 2020
Quick ratio	Quick assets divided by current liabilities	WIND	Jia et al., 2023
Financial development	The ratio of the financial sector output to GDP of the province	CSMAR	Dong & Yu, 2023
Economic development	The log of per capita GDP	CSMAR	Barro, 2001

4.2. Measures

4.2.1. Dependent variable

The dependent variable is SSCM performance. In line with previous research [41], [59], [116], we use Bloomberg's [10] environmental, social, and governance (ESG) scores to measure firms' SSCM performance. Bloomberg gathers ESG information from multiple sources, including firms' annual reports, public documents, and manufacturer and supplier announcements, and standardizes ESG scores by industry [59] to create a comprehensive set of data. Compared with Compustat, Bloomberg identifies seven times more suppliers of S&P 500 technology companies. This mitigates the methodological issues associated with the incompleteness of ESG information disclosed to the public [7]. Therefore, Bloomberg's supply chain data is attracting increased attention in the field of operations research (e.g., Kim and Davis [59]; Steven et al. [104]).

4.2.2. Independent variable

The independent variable is fintech adoption, measured as the density of fintech firms at the prefecture level. Following previous studies [34], [48], [70], [102], we obtain information about firms' fintech adoption by searching for key terms (e.g., "financial technology," "artificial intelligence," "cloud computing," "blockchain," "Internet of Things," and "big data") in the Tianyancha website. To improve the accuracy of our fintech adoption index, we exclude firms that have been in operation for less than 1 year, those with abnormal business conditions. The previously obtained companies' information is also filtered by searching for those with keywords related to financial services (e.g., "finance," "insurance," "payment," "credit," and "liquidation") to match the companies' business scope, and then keeping the matched samples. We then construct a fintech adoption index based on the number of fintech companies at the prefecture level. The higher the density of fintech firms, the higher the degree of fintech adoption.

4.2.3. Moderating variables

We collect our four moderating variables from the CNRDS and CSMAR databases. First, the total number of green patent applications (independent and joint) is used to measure green innovation [28], [42]. This information is sourced from the GPRD of CNRDS, which sources data from the China National Intellectual Property Administration and Google Patent and strictly adheres to World Intellectual Property Organization standards. Digital innovation policy is calculated as the total number of digital innovation standards development participation (including national and industry digital innovation standards) [67], [109]. Top management team forward-looking innovation orientation is measured as the number of years between a

digital innovation first appearing in the management discussion and analysis (MD&A) section of the annual report and the current year [57], [121]. Top management team persistent innovation orientation is measured as the number of years in which digital innovations feature in the MD&A section of the annual report [31], [63].

4.2.4. Control variables

To ensure the validity of our model, we control for variables that may enhance firms' SSCM performance. Specifically, we control for firm size, measured as the natural logarithm of a firm's total assets [20]; firm profitability, calculated as the return on assets[52]; firm leverage, calculated as total debt divided by total assets [52]; and quick ratio, calculated as the ratio of quick assets to current liabilities [54]. We also control for two key macroeconomic variables: financial development, measured as the ratio of financial industry output to provincial gross domestic product (GDP), and economic development, measured as the log of per capita GDP [5], [34]. The Hausman test confirms the applicability of the fixed effects regression model (p = 0.000).

4.3. Research model

First, we establish the baseline models as follows (see Table 1 for variable definitions):

$$SSCM_{i,t}=\beta_0+\beta_1 Fintech_{i,t}+\sum_{k=2}^{7}\beta_k \mathrm{Controls}_{i,t}+\varepsilon_{i,t} \quad (1)$$

$$SSCM_{i,t}=\beta_0+\beta_1 Fintech_{i,t}+\beta_2 GI_{i,t}+\beta_3 Fintech_{i,t}*GI_{i,t}+\sum_{k=4}^{9}\beta_k Controls_{i,t}+\varepsilon_{i,t} \quad (2)$$

$$SSCM_{i,t}=\beta_0+\beta_1 Fintech_{i,t}+\beta_2 DIP_{i,t}+\beta_3 Fintech_{i,t}*DIP_{i,t}+\sum_{k=4}^{9}\beta_k Controls_{i,t}+\varepsilon_{i,t} \quad (3)$$

$$SSCM_{i,t}=\beta_0+\beta_1 Fintech_{i,t}+\beta_2 MFI_{i,t}+\beta_3 Fintech_{i,t}*MFI_{i,t}+\sum_{k=4}^{9}\beta_k Controls_{i,t}+\varepsilon_{i,t} \quad (4)$$

$$SSCM_{i,t}=\beta_0+\beta_1 Fintech_{i,t}+\beta_2 MPI_{i,t}+\beta_3 Fintech_{i,t}*MPI_{i,t}+\sum_{k=4}^{9}\beta_k Controls_{i,t}+\varepsilon_{i,t} \quad (5)$$

Model 1 estimates the direct effect of fintech adoption on SSCM performance. Models 2, 3, 4, and 5, respectively, include the four moderators: green innovation (*GI*), digital innovation policy (*DIP*), top management team forward-looking innovation orientation (*MFI*), and top management team persistent innovation orientation (*MPI*), respectively. Control variables are included in each model.

The instrumental variable (IV) method system generalized method of moments (GMM), and difference-in-differences (DID) method are employed to ensure this study's robustness. First, the IV method is used in econometrics to address endogeneity issues. Traditional ordinary least squares estimates will produce biased and invalid results if the explanatory variable is correlated with an error term. Therefore, introducing IVs that are correlated to the endogenous explanatory variable but not the error term will generate unbiased parameter estimates [71]. Second, system GMM is used to address endogeneity and serial correlation issues in dynamic panel data models. System GMM uses moments from both difference GMM and level GMM, enhancing estimation accuracy [85]. We also employ the DID method to further mitigate endogeneity issues. DID is a causal inference method used to evaluate the effect of a policy by comparing changes in the treatment and control groups before and after policy implementation [74].

5. Results

5.1. Descriptive and correlation statistics

Table 2 presents the descriptive statistics, and Table 3 presents the correlation results. The coefficients between variables are small, suggesting that multicollinearity is not an issue.

Table 2. Descriptive statistics

VarName	Mean	SD	Min	Max
SSCM	35.318	8.432	20.390	70.224
Fintech	4.904	1.752	0.693	8.052
GI	9.417	37.879	0.000	736.000
DIP	28.039	7.512	15.396	100.000
MFI	59.403	31.828	6.691	99.188
MPI	55.891	32.708	5.881	99.754
Size	23.414	1.205	18.316	28.293
QR	1.349	1.781	0.033	35.127
ROA	0.044	0.115	-3.164	0.664
LEV	0.473	0.199	0.008	2.471
FDV	0.059	0.032	0.000	0.103
EDV	11.263	0.329	10.353	11.880

Table 3 Correlation matrix

Variables	SSCM	Fintech	GI	DIP	MFI	MPI	Size	QR	ROA	LEV	FDV	EDV
SSCM	1.000											
Fintech	0.064***	1.000										
GI	0.167***	0.060***	1.000									
DIP	0.206***	0.151***	0.063***	1.000								
MFI	0.033**	0.157***	0.119***	0.124***	1.000							
MPI	0.012	0.209***	0.143***	0.115***	0.832***	1.000						
Size	0.426***	0.052***	0.269***	0.074***	0.163***	0.101***	1.000					
QR	-0.064***	-0.004	-0.044***	0.039**	-0.136***	-0.096***	-0.293***	1.000				
ROA	0.115***	0.002	0.008	0.003	-0.065***	-0.048***	0.050***	0.140***	1.000			
LEV	0.070***	0.032**	0.099***	0.007	0.133***	0.091***	0.431***	-0.537***	-0.377***	1.000		
FDV	0.190***	0.211***	0.026	0.799***	0.125***	0.109***	0.045***	0.066***	-0.004	-0.015	1.000	
EDV	0.092	0.375	0.050	0.152	0.174	0.195	-	0.032	0.088	-	0.293	1.0

***	***	***	***	***	***	0.005	**	***	0.081 ***	***	00

Note: *** p < 0.01, ** p < 0.05, * p < 0.1.

5.2. Regression analysis

Table 4 presents the results of the regression analysis. Model 1 shows that fintech adoption positively influences SSCM performance (β = 2.663, $p < .01$), supporting H1. In Models 2, 3, 4, and 5, the coefficients on the interaction terms are all significantly positive (Model 2: β = 0.010, $p < .05$; Model 3: β = 0.024, $p < .01$; Model 4: β = 0.025, $p < .01$); Model 5: β = 0.018, $p < .01$). This suggests that green innovation, digital innovation policies, top management team forward-looking innovation orientation, and top management team persistent innovation orientation all strengthen the effect of fintech adoption on SSCM performance, supporting H2, H3, H4, and H5.

Table 4 Regression results

	Model 1 SSCM	Model 2 SSCM	Model 3 SSCM	Model 4 SSCM	Model 5 SSCM
Fintech	2.663***	2.610***	2.958***	1.965***	2.282***
	(0.346)	(0.331)	(0.337)	(0.385)	(0.355)
Size	5.149***	5.182***	5.012***	4.665***	4.801***
	(0.298)	(0.480)	(0.469)	(0.486)	(0.485)
QR	-0.023	-0.022	-0.012	-0.018	-0.018
	(0.081)	(0.076)	(0.076)	(0.075)	(0.076)
ROA	-1.792**	-1.786**	-1.755**	-1.575**	-1.652**
	(0.810)	(0.728)	(0.717)	(0.715)	(0.720)
LEV	-5.383***	-5.354***	-5.418***	-5.413***	-5.417***
	(1.061)	(1.379)	(1.376)	(1.383)	(1.381)
FDV	-1.630	-1.550	18.051***	-4.216	-2.988
	(2.975)	(2.810)	(6.264)	(2.707)	(2.771)
EDV	17.301***	17.319***	17.934***	15.933***	16.654***
	(0.930)	(1.074)	(1.073)	(1.126)	(1.082)
GI		-0.007			
		(0.009)			
Fintech_GI		0.010**			
		(0.005)			
DIP			-0.099***		
			(0.025)		

Fintech_DIP			0.024***		
			(0.005)		
MFI				0.079***	
				(0.018)	
Fintech_MFI				0.025***	
				(0.006)	
MPI					0.054***
					(0.016)
Fintech_MPI					0.018***
					(0.006)
_cons	-290.401***	-291.113***	-294.205***	-264.976***	-276.231***
	(10.373)	(14.073)	(14.037)	(15.751)	(14.707)
Observations	4038	4038	4038	4038	4038
R^2	0.399	0.402	0.406	0.411	0.406
Adj. R^2	0.217	0.401	0.404	0.409	0.405
F-statistic	294.017	109.064	110.200	112.794	109.649

Note: *** p < 0.01, ** p < 0.05, * p < 0.1. Standard errors in parentheses.

5.3. Endogeneity checks

5.3.1. Instrumental variable method

We adopt the IV method to check for omitted variables that may affect SSCM performance. We take the average fintech value of all firms in a province in the same year and create interaction terms with the moderating variables. Our results remain significant (see Table 5). Moreover, the model passes the non-identification test ($p < .1$), the Cragg–Donald Wald F test, and the over-identification test.

Table 5 Instrumental variable regression

	Model 1 SSCM	Model 2 SSCM	Model 3 SSCM	Model 4 SSCM	Model 5 SSCM
Fintech	3.965***	3.875***	4.571***	2.982***	3.486***
	(0.426)	(0.427)	(0.435)	(0.460)	(0.442)
Size	5.052***	5.112***	4.801***	4.549***	4.713***
	(0.299)	(0.299)	(0.300)	(0.306)	(0.307)
QR	-0.014	-0.013	0.007	-0.005	-0.006
	(0.081)	(0.081)	(0.081)	(0.080)	(0.081)
ROA	-1.854**	-1.844**	-1.797**	-1.603**	-1.701**
	(0.811)	(0.810)	(0.810)	(0.806)	(0.809)
LEV	-5.483***	-5.438***	-5.574***	-5.682***	-5.694***
	(1.062)	(1.062)	(1.062)	(1.057)	(1.061)

FDV	-7.649**	-7.491**	16.980***	-10.379***	-9.827***
	(3.191)	(3.188)	(5.591)	(3.189)	(3.197)
EDV	15.950***	15.973***	16.878***	15.422***	15.866***
	(0.966)	(0.966)	(0.972)	(1.004)	(0.987)
Fintech_GI		0.018***			
		(0.004)			
GI		-0.014**			
		(0.006)			
Fintech_DIP			0.051***		
			(0.008)		
DIP			-0.124***		
			(0.024)		
Fintech_MFI				0.045***	
				(0.006)	
MFI				0.079***	
				(0.014)	
Fintech_MPI					0.039***
					(0.006)
MPI					0.051***
					(0.012)
Observations	4024	4024	4024	4024	4024
R^2	0.397	0.398	0.398	0.404	0.399
Adj. R^2	0.216	0.217	0.216	0.225	0.218
F-statistic	296.614	233.655	236.835	242.459	238.696

Note: *** p < 0.01, ** p < 0.05, * p < 0.1. Standard errors in parentheses.

5.3.2. Generalized method of moments regression analysis

Following Sartal et al. [96], we employ system GMM regression analysis to further examine the robustness of our findings. The results (see Table 6) indicate that the IVs meet the conditions for use in system GMM and that the fintech coefficient is significantly positive at the 1% level. This suggests that fintech adoption continues to have a positive effect on SSCM performance, confirming the robustness of the findings.

Table 6 Dynamic GMM regression

	SSCM
L.SSCM	0.366***
	(0.063)
Fintech	148.346***
	(13.882)
Observations	2182

AR(1)	0.088
AR(2)	0.298
Hansen	0.136

Note: *** p < 0.01, ** p < 0.05, * p < 0.1. Standard errors in parentheses.

5.3.3. Difference-in-differences analysis

In 2019, the People's Bank of China [86] published the *FinTech Development Plan (2019–2021)*, which outlines the principles, objectives, key tasks, and support measures for fintech adoption in China. This policy represents an exogenous shock. However, the degree of fintech adoption differs by region; therefore, firms in regions with weaker fintech adoption experience a relatively larger effect from fintech adoption. This provides an opportunity to develop a DID model to identify the causal relationship between fintech adoption and SSCM performance. Firms in cities in which the level of fintech adoption is below the average at the end of 2018 are assigned a value of 1 (treatment group), while firms in cities in which the level of fintech adoption is above the average at the end of 2018 are assigned a value of 0 (control group). The DID model is as follows:

$$\text{SSCM}_{i,t}=\alpha+\beta Treat_{i,t}\times Ct_{i,t}+\gamma\text{Controls}+\eta_i+\lambda_t+\varepsilon_{i,t},$$

where $Treat_{i,t}$ is an indicator for the experimental group, and $Ct_{i,t}$ is a time dummy variable set to 1 for the year 2020 and later and 0 for earlier years. The other variables are the same as those described previously. η_i and λ_t represent firm-level and year-level fixed effects, respectively. Table 7 reports the DID regression results. As expected, the coefficient for $Treat_{i,t} \times Ct_{i,t}$ is significantly positive ($p < .05$), indicating that firms located in regions that are more affected by the fintech policy will have a greater improvement in SSCM performance.

Table 7 Difference in differences (DID) regression

DID	Parallel trends
SSCM	SSCM

Treat_Ct	0.678**	
	(0.320)	
Year2018_Treat		0.400
		(0.459)
Year2019_Treat		0.111
		(0.438)
Year2021_Treat		0.648
		(0.434)
Year2022_Treat		1.178**
		(0.552)
Size	3.319***	3.355***
	(0.294)	(0.293)
QR	0.009	0.011
	(0.075)	(0.075)
ROA	-1.489**	-1.499**
	(0.758)	(0.758)
LEV	-4.657***	-4.682***
	(0.992)	(0.992)
FDV	11.371	8.951
	(12.314)	(12.605)
EDV	-1.209	-1.432
	(1.424)	(1.448)
_cons	-29.582*	-28.228
	(17.413)	(17.627)
Observations	4035	4038
R^2	0.476	0.477
Adj. R^2	0.315	0.316
F-statistic	254.724	200.837

Note: *** p < 0.01, ** p < 0.05, * p < 0.1. Standard errors in parentheses.

The parallel trend assumption is important in unbiased DID estimates. Following Bertrand and Mullainathan [8], we include interactions between the treatment and pre-policy year dummy variables (*year2018*, *year2019*) to capture any significant pre-policy differences in SSCM between the two groups. Table 7 shows that *Treat* and pre-policy year dummies are not significantly different from 0, indicating no significant difference in SSCM between the two groups prior to policy implementation, satisfying the parallel trend assumption. To avoid

multicollinearity issues, the regression model excludes the policy implementation period of 2020. Among interactions with post-policy year dummies, only *Treat* × *year2022* is significantly positive at the 5% level, reflecting a 1-year lag in the policy effect.

5.4. Robustness checks

We perform additional robustness checks to validate our results. First, firms with a return on assets of ≤ 0 are excluded from the sample [36], and the results remain robust. Second, we employ a high-dimensional fixed effect to control for the industry of the sample [32], thus avoiding variables that do not change over time, such as the firm's industry category, which are omitted in fixed effects models that control for individual effects. Table 8 and Table 9 show the results of the robustness checks, which align with the baseline results, suggesting that our model is relatively robust and reasonable.

Table 8 Robustness checks I

	(1) SSCM	(2) SSCM	(3) SSCM	(4) SSCM	(5) SSCM
Fintech	2.752***	2.690***	3.088***	2.100***	2.362***
	(0.387)	(0.383)	(0.389)	(0.429)	(0.404)
Size	5.994***	6.038***	5.803***	5.365***	5.530***
	(0.358)	(0.582)	(0.570)	(0.596)	(0.592)
QR	-0.137	-0.136	-0.118	-0.122	-0.134
	(0.101)	(0.099)	(0.100)	(0.101)	(0.099)
ROA	-2.057	-2.110	-2.085	-1.560	-1.476
	(2.316)	(3.251)	(3.235)	(3.235)	(3.270)
LEV	-8.879***	-8.856***	-8.792***	-8.705***	-8.712***
	(1.565)	(2.090)	(2.080)	(2.119)	(2.103)
FDV	-4.764	-4.706	16.477**	-7.505**	-6.101**
	(3.289)	(3.063)	(6.763)	(2.967)	(3.030)
EDV	16.608***	16.621***	17.333***	15.372***	15.949***
	(1.040)	(1.206)	(1.201)	(1.238)	(1.196)
GI		-0.009			
		(0.009)			
Fintech_GI		0.011**			
		(0.005)			
DIP			-0.106***		

			(0.027)		
Fintech_DIP			0.027***		
			(0.006)		
MFI				0.081***	
				(0.020)	
Fintech_MFI				0.027***	
				(0.006)	
MPI					0.060***
					(0.018)
Fintech_MPI					0.019***
					(0.006)
_cons	-300.886***	-301.738***	-304.617***	-273.954***	-284.245***
	(11.408)	(15.454)	(15.410)	(17.367)	(16.112)
Observations	3629	3629	3629	3629	3629
R^2	0.410	0.413	0.417	0.422	0.417
Adj. R^2	0.205	0.412	0.416	0.421	0.416
F-statistic	267.154	100.709	102.479	104.750	101.702

Note: *** p < 0.01, ** p < 0.05, * p < 0.1. Standard errors in parentheses.

Table 9 Robustness checks II

	(1) SSCM	(2) SSCM	(3) SSCM	(4) SSCM	(5) SSCM
Fintech	2.663***	2.610***	2.958***	1.965***	2.282***
	(0.319)	(0.317)	(0.315)	(0.344)	(0.328)
Size	5.149***	5.182***	5.012***	4.665***	4.801***
	(0.382)	(0.381)	(0.375)	(0.385)	(0.385)
QR	-0.023	-0.022	-0.012	-0.018	-0.018
	(0.066)	(0.066)	(0.067)	(0.065)	(0.066)
ROA	-1.792**	-1.786**	-1.755**	-1.575**	-1.652**
	(0.780)	(0.781)	(0.778)	(0.783)	(0.777)
LEV	-5.383***	-5.354***	-5.418***	-5.413***	-5.417***
	(1.186)	(1.186)	(1.188)	(1.192)	(1.185)
FDV	-1.630	-1.550	18.051***	-4.216	-2.988
	(2.889)	(2.890)	(6.451)	(2.849)	(2.871)
EDV	17.301***	17.319***	17.934***	15.933***	16.654***
	(0.984)	(0.981)	(0.994)	(1.026)	(1.003)
GI		-0.007			
		(0.008)			
Fintech_GI		0.010**			
		(0.004)			
DIP			-0.099***		
			(0.029)		
Fintech_DIP			0.024***		
			(0.005)		

MFI				0.079***	
				(0.014)	
Fintech_MFI				0.025***	
				(0.004)	
MPI					0.054***
					(0.013)
Fintech_MPI					0.018***
					(0.005)
_cons	-290.426***	-291.139***	-294.230***	-265.020***	-276.266***
	(11.887)	(11.882)	(11.880)	(13.138)	(12.556)
Observations	4024	4024	4024	4024	4024
R^2	0.828	0.829	0.830	0.832	0.830
Adj. R^2	0.777	0.778	0.779	0.781	0.779
F-statistic	210.487	165.847	171.320	177.115	169.768

Note: *** p < 0.01, ** p < 0.05, * p < 0.1. Standard errors in parentheses.

5.5. Heterogeneity tests

We also conduct a heterogeneity analysis based on firm ownership to further validate our findings. Tables 10 and 11 show the results for state-owned enterprises (SOEs) and non-SOEs, respectively. The moderating effect of green innovation on the relationship between fintech adoption and SSCM performance is only significant for SOEs ($\beta = 0.021$, $p < .01$), not non-SOEs ($\beta = 0.001$). This may be because non-SOEs fail to invest adequately in green innovation. Additionally, the effect of fintech adoption on SSCM performance is stronger for non-SOEs than for SOEs. Table 12 summarizes the results.

Table 10 Heterogeneity tests (state-owned enterprises)

	Model 1 SSCM	Model 2 SSCM	Model 3 SSCM	Model 4 SSCM	Model 5 SSCM
Fintech	2.532***	2.392***	2.817***	2.005***	2.312***
	(0.501)	(0.510)	(0.532)	(0.610)	(0.569)
Size	6.086***	5.996***	5.942***	5.570***	5.819***
	(0.558)	(0.864)	(0.857)	(0.893)	(0.881)
QR	0.293*	0.298	0.305	0.247	0.314
	(0.176)	(0.208)	(0.212)	(0.211)	(0.204)
ROA	-2.628**	-2.560**	-2.706**	-2.454**	-2.471**
	(1.192)	(1.100)	(1.118)	(1.104)	(1.072)
LEV	-9.171***	-8.935***	-9.274***	-9.223***	-9.231***
	(1.834)	(2.423)	(2.477)	(2.556)	(2.507)

FDV	-4.144	-4.184	8.013	-7.752*	-5.494
	(4.509)	(4.433)	(9.342)	(4.231)	(4.402)
EDV	14.624***	14.847***	15.000***	13.066***	13.763***
	(1.340)	(1.602)	(1.601)	(1.695)	(1.653)
GI		-0.010			
		(0.016)			
Fintech_GI		0.021***			
		(0.007)			
DIP			-0.062*		
			(0.036)		
Fintech_DIP			0.018**		
			(0.008)		
MFI				0.086***	
				(0.028)	
Fintech_MFI				0.023***	
				(0.008)	
MPI					0.056**
					(0.025)
Fintech_MPI					0.018*
					(0.009)
_cons	-279.609***	-279.395***	-280.780***	-252.272***	-265.638***
	(16.019)	(21.668)	(21.547)	(24.341)	(22.788)
Observations	1757	1757	1757	1757	1757
R^2	0.382	0.394	0.385	0.396	0.390
Adj. R^2	0.196	0.391	0.382	0.393	0.386
F-statistic	119.209	45.858	43.917	45.791	44.509

Note: *** p < 0.01, ** p < 0.05, * p < 0.1. Standard errors in parentheses.

Table 11 Heterogeneity tests (Non-state-owned enterprises)

	Model 1 SSCM	Model 2 SSCM	Model 3 SSCM	Model 4 SSCM	Model 5 SSCM
Fintech	3.053***	3.028***	3.290***	2.199***	2.515***
	(0.480)	(0.435)	(0.433)	(0.517)	(0.478)
Size	4.609***	4.608***	4.481***	4.242***	4.293***
	(0.356)	(0.574)	(0.557)	(0.579)	(0.580)
QR	-0.091	-0.091	-0.079	-0.078	-0.090
	(0.091)	(0.082)	(0.081)	(0.079)	(0.079)
ROA	-1.535	-1.532	-1.328	-1.319	-1.421
	(1.103)	(1.057)	(1.047)	(1.052)	(1.057)
LEV	-3.378***	-3.370**	-3.300**	-3.382**	-3.370**
	(1.306)	(1.628)	(1.629)	(1.619)	(1.626)
FDV	-1.786	-1.800	23.192***	-2.980	-2.764
	(3.957)	(3.621)	(8.027)	(3.557)	(3.598)
EDV	20.010***	20.079***	20.834***	18.851***	19.427***

	(1.301)	(1.501)	(1.484)	(1.540)	(1.462)
GI		0.004			
		(0.008)			
Fintech_GI		0.001			
		(0.004)			
DIP			-0.125***		
			(0.032)		
Fintech_DIP			0.029***		
			(0.007)		
MFI				0.066***	
				(0.024)	
Fintech_MFI				0.025***	
				(0.008)	
MPI					0.049**
					(0.020)
Fintech_MPI					0.018**
					(0.008)
_cons	-311.664***	-312.348***	-317.300***	-289.929***	-298.097***
	(14.100)	(19.238)	(19.103)	(21.112)	(19.462)
Observations	2281	2281	2281	2281	2281
R^2	0.422	0.422	0.431	0.430	0.427
Adj. R^2	0.242	0.420	0.429	0.428	0.425
F-statistic	181.510	69.239	71.969	71.076	69.775

Note: *** p < 0.01, ** p < 0.05, * p < 0.1. Standard errors in parentheses.

Table 12 Hypotheses summary table

Hypotheses	**Supporting/Not Supporting**
H1. Fintech adoption positively influences SSCM performance.	Supporting
H2. Green innovation positively moderates the relationship between fintech adoption and SSCM performance.	Supporting
H3. Digital innovation policies positively moderate the relationship between fintech adoption and SSCM performance.	Supporting
H4a. The forward-looking innovation orientation of top management team positively affects the relationship between Fintech adoption and SSCM performance.	Supporting
H4b. The persistent innovation orientation of top management team positively affects the relationship between Fintech adoption and SSCM performance.	Supporting

6. Discussion

This study empirically demonstrates the positive influence of fintech adoption on firms' SSCM performance and the moderating roles of green innovation, digital innovation policies,

top management team forward-looking innovation orientation, and top management team persistent innovation orientation. Notably, our analysis of heterogeneity across corporate ownership structures revealed that green innovation has exerted a substantial influence exclusively on fintech adoption by state-owned enterprises in the context of sustainable supply chain practices. Furthermore, the adoption of fintech by non-state-owned enterprises appears to have a more significant impact on their SSCM performance. This study is one of the first to investigate the technology adoption–sustainability relationship from an IIE perspective.

6.1. Theoretical implications

This study makes two theoretical contributions to the innovation literature. First, while previous studies have highlighted the beneficial effects of fintech adoption on firms' sustainability performance (e.g., Pizzi et al. [88]; Soni et al. [103]; Taneja et al. [108]), research on the effect of fintech adoption on SSCM performance is lacking. Our study demonstrates that fintech adoption can significantly enhance firms' SSCM performance, particularly for non-SOEs and firms in regions that are affected more by digital innovation policies.

Second, we explore the technology adoption–sustainability relationship from an IIE perspective. Previous research has emphasized the value of IIEs for stimulating innovation, generating new knowledge, enhancing competitiveness, and bringing economic benefits [76], [93]. However, the role of IIE characteristics in the relationship between fintech adoption and SSCM performance has not been explored. Therefore, we extend the IIE research [33], [62], [107] by examining the moderating role of four IIE characteristics, namely green innovation, digital innovation policies, top management team forward-looking and persistent innovation orientation, in the relationship between fintech adoption and SSCM performance. These

findings provide new insights into how firms can leverage innovation to improve their sustainable practices.

6.2. Managerial implications

This study has three managerial implications. First, fintech can be used to optimize SCM and enhance sustainability by integrating big data, AI, and other technologies to collect real-time data from across the supply chain, enabling firms to more accurately predict market trends, fluctuations, and inventory levels. Additionally, fintech adoption facilitates the documentation and sharing of transaction data within the supply chain, enhancing information transparency, building trust between suppliers and buyers, and improving supplier compliance and social responsibility. Data-driven decision-making reduces resource wastage caused by information asymmetry or lag and enhances the operational efficiency and responsiveness of the supply chain, boosting supply chain sustainability.

Second, our study demonstrates the important role of fintech in enabling firms to sustainably manage their supply chains. Therefore, policymakers, investors, and other stakeholders should encourage firms to adopt fintech. To improve their SSCM performance, firms should invest in green innovation, actively participate in the creation of digital innovation policies, and encourage forward-looking innovation orientation and persistent innovation orientation in their management teams.

Third, policymakers should formulate policies and regulations that encourage the adoption of fintech for SCM. This may include incentives for green innovations such as tax breaks, subsidies, and R&D funding. Additionally, policymakers should establish fintech standards to promote its widespread application in SCM. Through these measures, they can

promote not only the development of fintech but also the efficiency and sustainability of supply chains, laying a solid foundation for long-term economic growth.

7. Conclusion

Adopting fintech for SCM may help to promote SSCM, improving not only firm competitiveness but also environmental sustainability. Our findings suggest that fintech adoption can significantly enhance firms' SSCM performance, especially for non-SEOs. Moreover, green innovation, digital innovation policies, top management team forward-looking innovation orientation and persistent innovation orientation reinforce the positive effect of fintech adoption on SSCM performance.

Our study provides several opportunities for future research. First, as more information becomes available, future researchers could examine the long-term effects of fintech adoption on SCM. Second, researchers could explore other factors that moderate the relationship between fintech application and SSCM performance, including supply chain disruptions, dynamism, and complexity [13], [38], [123]. Moreover, future researchers could examine other industries or countries to improve the generalizability of our findings.

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